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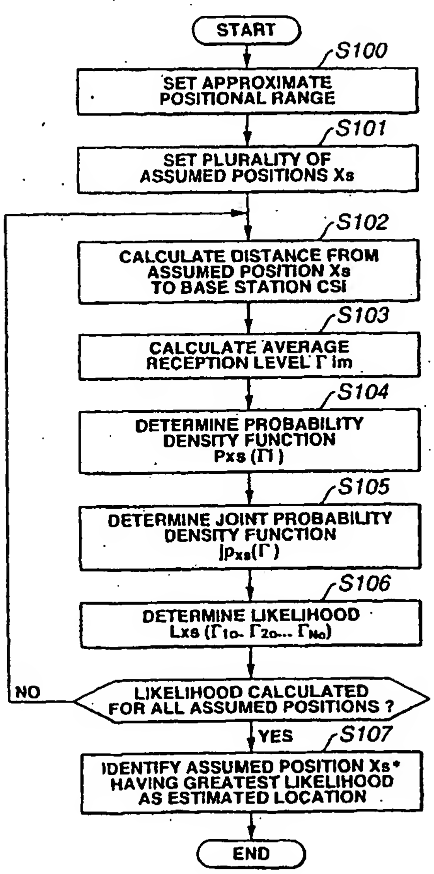
(54) Title: METHOD FOR DETECTING LOCATION OF MOBILE TERMINAL, AND STORAGE MEDIUM STORING COMPUTER-OPERATED LOCATION DETECTING



(57) Abstract: An object of the invention is to determine the location of a mobile terminal as a maximum likelihood estimate value, in a mobile communications system comprising a plurality of base stations, at least one mobile terminal capable of communicating with the base stations, and a center station capable of communicating with the base stations and/or mobile terminal. The probability distribution indicating the variation in the reception level from respective base stations CS_i at a plurality of points within a prescribed range in which the mobile terminal has a possibility of being present is determined for these points on the basis of a base station database storing, at the least, positional information for the respective base stations CS_i. A likelihood corresponding to the aforementioned probability distribution is determined with respect to the reception level values γ_{o}; from the base stations CS_i ($i = 1$ to N) measured by the mobile station, and the point having the greatest likelihood value is determined to be the estimated location of the mobile terminal. Selected drawing Fig. 4

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DESCRIPTION

METHOD FOR DETECTING LOCATION OF MOBILE TERMINAL, AND STORAGE MEDIUM STORING COMPUTER-OPERATED LOCATION DETECTING PROGRAM

TECHNICAL FIELD

The present invention relates to location detecting technology for a mobile terminal, such as a mobile radio terminal, or the like, and more particularly, to location detecting technology for detecting the location of a mobile terminal, by taking account of the probability variation of a signal reception level.

BACKGROUND ART

In the prior art, technology for identifying (detecting) the location of a mobile terminal has been proposed for mobile communications systems comprising a plurality of base stations, at least one mobile terminal capable of transmitting and receiving signals with respect to the base stations, and a center station (control station) capable of communicating with the base stations and/or the mobile station(s).

For example, there exists a method wherein a radio wave emitted by a mobile terminal, such as a portable telephone, is received by a base station, the distance of the mobile terminal from the base station is identified on

the basis of the difference in the intensity and/or arrival time of the radio wave received by the respective base stations, and the location of the mobile terminal is identified on the basis of the distances between the mobile terminal and the plurality of base stations.

Furthermore, there also exists, conversely, a method wherein radio waves emitted by bases station are received by a mobile terminal, the distance of the mobile terminal from the base stations is identified on the basis of the difference in the intensity and/or arrival time of the radio waves from the respective base stations, and the location of the mobile terminal is identified on the basis of the distances between the mobile terminal and the plurality of base stations.

Specific, known examples of such a method include position identifying methods based on curve intersection methods, an SX method (Spherical Intersection Method), PX method (Plain Intersection Method), or the like. These various techniques are commonly known to specialists in this field, and more details thereof are described in (1) Ralph O. Schmidt, "A New Approach to Geometry of Range Difference Location," IEEE Transactions on Aerospace and Electronic Systems. Vol.AES-8, No.6, November 1972, and (2) Julius O. Smith, Jonathan S. Abel. "Closed-Form Least-Squares Source Location Estimation from Range-Difference

Measurements" IEEE Transactions On Acoustics, Speech, and Signal Processing, VOL. ASSP-35, NO.12, December 1987.

DISCLOSURE OF THE INVENTION

These conventional location identifying methods involve problems of the following kind. For example, in a curve intersection method, since it is necessary to resolve a non-linear equation, the calculational processing load is very large. On the other hand, in the case of a SX method or PX method, the solution can be derived on the basis of a linear equation, so they do not involve this problem of the curve intersection method, but these methods are greatly affected by error in observation results, and the like, and therefore it is difficult to identify a location with sufficient accuracy.

There also exist the following problems. The reception level of a radio wave from a base station received by a mobile terminal varies greatly according to the combination of the long section variation due to distance attenuation, short section variation due to buildings, and the like, and momentary variation caused by movement within an electrical field. Here, assuming that the short section variation follows a prescribed probability distribution, then desirably, the location of a mobile terminal should be identified on the basis of a maximum likelihood estimate approach. However, in the conventional methods described

above, the short section variation is not taken into account, or if it is, it is treated simply as a measurement error, and consequently, in either case, the location of the mobile terminal thus determined does not represent a maximum likelihood estimate.

Therefore, it is an object of the present invention to determine the location of a mobile terminal as a maximum likelihood estimate value, whilst considering a trade off between the calculational processing load and the accuracy of the estimate.

The location detecting method of the present invention is a location detecting method for a mobile communications system constituted by a plurality of base stations, a mobile terminal and a control station, wherein signals are sent by the base stations, numbers unique to each base station being included in the signals from the base stations, the mobile terminal receives the signals from one or a plurality of N base stations, the reception level Γ_i from the i^{th} base station thereof is measured and stored, the 1^{st} to N^{th} reception levels are transferred to a control station via communicating base stations, and at the control station, the location of the mobile terminal is identified on the basis of a database created on the basis of the base station numbers, base station co-ordinates, and reception levels obtained previously either by measurement or

simulation, or both measurement and simulation, of radio wave propagation at respective points in the service area of each base station, and the reception levels sent by the mobile terminal, characterized in that it comprises the steps of: setting co-ordinate points of a two-dimensional or three-dimensional mesh shape or grid shape, across the whole service area of each base station; determining an estimate value for the average reception level, corresponding to each base station having received the signals (hereinafter, called "signal receiving base station"), at each candidate point from among said co-ordinate points, and taking the estimate value as an average value and determining the probability density function of the variation of the average value; integrating the probability density functions determined for the candidate points, for a given range, on the basis of the measured reception levels, for each signal receiving base station, at each of the candidate points; determining the likelihood of a candidate point by multiplying together the values obtained by the integration for each signal receiving base station, at each of the candidate points; and detecting the candidate point having the greatest likelihood value as an estimated location of the mobile terminal.

Moreover, the method of the present invention also comprises the steps of: determining an estimate value of

the average reception level, corresponding to each base station having received the signals (hereinafter, called "signal receiving base station"), at each candidate point from among said co-ordinate points, and taking the estimate value as an average value and determining the probability density function of the variation of the average value; substituting the measured reception levels into the probability density function determined for each candidate point, on the basis of the reception levels measured for each signal receiving base station at each candidate point; determining the likelihood of the candidate point by multiplying together the values obtained by the substitution for each signal receiving base station, at each of the candidate points; and detecting the candidate point having the greatest likelihood value as the estimated location of the mobile terminal.

Furthermore, the method of the present invention also comprises the steps of: determining an estimate value of the average reception level, corresponding to each base station having received the signals (hereinafter, called "signal receiving base station"), at each candidate point from among said co-ordinate points, and taking the estimate value as an average value and determining the probability density function of the variation of the average value; substituting measurement data into the probability density function determined for each candidate point, on the basis

of the reception levels measured for each signal receiving base station at each candidate point, and multiplying by a prescribed value; determining the likelihood of the candidate point by multiplying together the values obtained by the substitution for each signal receiving base station, at each of the candidate points; and detecting the candidate point having the greatest likelihood value as the estimated location of the mobile terminal.

Suitably, the likelihood may be calculated by estimating parameters relating to the probability density function and propagation characteristics equation for each corresponding base station, individually.

Suitably, the likelihood may be calculated by estimating parameters relating to the probability density function and propagation characteristics equation for each mesh, or each grid point, individually.

Suitably, the likelihood may be calculated using a propagation characteristics equation having different probability density functions according to the time of day, day of the week, season of the year, traffic density, or the like, in cases where propagation characteristics taking account of buildings, and topographical conditions, and the like, are expected.

Suitably, in cases where the base stations have a sector composition, the co-ordinates and the angle of orientation of the sector may be linked, a joint

probability being set which factors in the difference between each sector angle of orientation, and the likelihood being determined by multiplying the joint probability by the likelihood corresponding to the co-ordinates.

Suitably, a long section propagation estimate equation and a short section average probability density may be determined according to building information or map information, from propagation characteristics which take account of buildings or topographical conditions between the co-ordinates and the base stations.

Suitably, a plurality of estimate locations, in other words, an estimate area, wherein the likelihood is greater than a certain prescribed value, may be set.

Suitably, the propagation delay time may be used instead of the reception level.

The method for creating a database according to the present invention is a method for creating a database used for detecting the position of a mobile terminal in a mobile communications system constituted by a plurality of base stations, a mobile terminal and a control station, characterized in that it comprises the steps of: storing base station numbers, base station co-ordinates, and reception levels obtained previously either by measurement or simulation, or both measurement and simulation, of radio wave propagation at respective points in the service area

of each base station, as data, in mutually associated fashion; detecting an idiosyncrasy point at which a reception level is measured which is peculiar when compared to the reception level at other nearby points, on the basis of the aforementioned stored data; and storing the propagation characteristics parameters corresponding to the detected idiosyncrasy point.

Furthermore, the method for creating a database according to the present invention is a method of creating a database used for detecting the position of a mobile terminal in a mobile communications system constituted by a plurality of base stations, a mobile terminal and a control station, wherein, in order to determine the standard deviation which is one parameter of the probability density function, a plurality of reception antennas are used and measured simultaneously, and a database is created by identifying measurement positions by the order of several metres.

The location identifying method according to the present invention is a location identifying method for a mobile communications system comprising a plurality of base stations, at least one mobile terminal capable of communicating with the base stations, and a center station capable of communicating with the base stations and/or the mobile terminal, for determining the estimated location of

the mobile terminal, on the basis of the reception level values $\Gamma_k(CS_i)$ of signals from base stations CS_i ($i = 1 - N$; $N \geq 1$) as measured at the mobile terminal, and a base station database storing at the least positional information for the base stations CS_i, wherein the likelihood of a reception level value $\Gamma_k(CS_i)$ is determined for a plurality of points, on the basis of the probability distribution indicating the variation of the reception level of the signals from the base stations CS_i at that point, and the point having the greatest likelihood value is determined as the estimated location of the mobile terminal.

The location identifying method according to the present invention is a location identifying method for a mobile communications system comprising a plurality of base stations, at least one mobile terminal capable of communicating with the base stations, and a center station capable of communicating with the base stations and/or the mobile terminal, for determining the estimated location of the mobile terminal, on the basis of the reception level values $\Gamma_k(CS_i)$ of signals from base stations CS_i ($i = 1 - N$; $N \geq 1$) as measured at the mobile terminal, and a base station database storing at the least positional information for the base stations CS_i, comprising: a first step of setting an approximate positional range for the

mobile terminal, a second step of setting a plurality of representative points X_s ($s = 1 - M$) in the approximate positional range; a third step of determining a probability density function $p_s(\gamma_i)$ indicating the variation of the reception level from a base station CS_i at the representative point X_s, on the basis of the distance d (X_s, CS_i) between the representative point X_s and the base station CS_i as obtained by referring to the aforementioned base station database; a fourth step of determining the joint probability density function $jp_s(\gamma)$ by the equation $jp_s(\gamma) = p_s(\gamma_1) \times p_s(\gamma_2) \times \cdots \times p_s(\gamma_N)$; a fifth step of determining the likelihood $L_s(jp_s(\gamma) \mid \Gamma_k)$ corresponding to the probability distribution specified by the joint probability density function $jp_s(\gamma)$; and a sixth step of determining the representative point X_s^* having the greatest likelihood value $L_s(jp_s(\gamma) \mid \Gamma_k)$ as the estimated location of the mobile terminal.

The location identifying system according to the present invention is a mobile terminal location identifying system for identifying the location of a mobile terminal capable of communicating with a plurality of base stations, comprising a center station having a function for determining the estimated location of a mobile terminal, on the basis of the reception level value $\Gamma_k(CS_i)$ of a signal

from a base station CS_i ($i = 1 - N$; $N \geq 1$) as measured by the mobile terminal, and a base station database storing, at the least, positional information for the base stations CS_i, the center station also comprising means or functions for executing the location identifying method according to the present invention.

The program according to the present invention is characterized in that it causes the respective steps of the location detecting method of the present invention to be executed in a computer. The program according to the present invention may be installed or loaded into a computer by means of a storage medium of various types, such as a CD-ROM, magnetic disk, semiconductor memory, or the like.

Moreover, in the present specification, reference to "means" does not only signify physical device, but also includes cases where the functions provided by said means are achieved by software. Moreover, the functions of one means may be achieved by two or more physical means, and the functions of two or more means may be achieved by one physical means.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the composition of a mobile communications system in first embodiment of the present invention;

Fig. 2 is a block diagram showing the functional composition of a center station;

Fig. 3 is a diagram for illustrating the data structure of a base station database;

Fig. 4 is a flowchart for describing the processing sequence of the location identifying means;

Fig. 5 is a diagram for describing the data structure of a base station database in a modification example;

Fig. 6 is a diagram for describing the data structure of a base station database in a modification example;

Fig. 7 is a diagram for describing the positional configuration of base stations in an experiment;

Fig. 8 is a diagram for describing simulation results;

Fig. 9 is a diagram for describing simulation results;

Fig. 10 is a diagram for describing simulation results;

Fig. 11 is a diagram for describing simulation results;

Fig. 12 is a diagram for describing results obtained on the basis of measurement data;

Fig. 13 is a diagram for describing results obtained on the basis of measurement data;

Fig. 14 is a diagram for describing an example of idiosyncrasy points;

Fig. 15 is a diagram for describing an example of idiosyncrasy points;

Fig. 16 is a diagram for describing an example of idiosyncrasy points;

Fig. 17 is a diagram for describing an example of idiosyncrasy points;

Fig. 18 is a diagram for describing an example of idiosyncrasy points;

Fig. 19 is a diagram for describing an example of idiosyncrasy points;

Fig. 20 is a diagram for describing an example of idiosyncrasy points; and

Fig. 21 is a diagram for describing an example of idiosyncrasy points.

BEST MODE FOR CARRYING OUT THE INVENTION

(First embodiment)

Below, embodiments of the present invention are described with reference to the drawings.

Fig. 1 is a conceptual diagram showing the composition of a mobile communications system forming first embodiment of the present invention. The constituent elements of this system are: a mobile terminal 10, a plurality of base stations CS composed so as to communicate with the mobile

terminal 10, and a center station (control station) 90 composed so as to communicate with the base stations CS.

In principle, the mobile terminal 10 and base stations CS have the same functional composition of a conventional mobile communications system constituted by PHS, portable telephones, or the like. For example, the base stations CS have the function of including an identification ID (identification information) that is unique to that base station into a radio signal, when sending it, and the like. Moreover, the mobile terminal 10 has the function of receiving radio waves from a base station CS_i (where $i = 1 \sim N$; N being the number of base stations capable of communicating with the mobile terminal 10; $N \geq 1$), and measuring and recording the reception level Γ_o (Γ_{1o}, Γ_{2o}, … Γ_{No}) thereof (dB), and the like.

The base stations CS contained the mobile terminal 10 within a control area (service area; hereinafter called "zone or cell"), or the base stations CS communicating with the mobile terminal 10, receive the aforementioned reception level Γ_{io} for the 1st to the Nth base station, from the mobile terminal 10, and send same to the center station 90. It is also possible to adopt a composition where the reception level Γ_{io} is sent directly from the mobile terminal 10 to the center station 90, rather than via the base station.

Fig. 2 shows the functional composition of a center station 90. As shown in Fig. 2, the center station 90 comprises, at the least, a base station database 91 for storing the positional information of the base stations CS and location identifying means 92 for identifying the location of a mobile terminal 10, and hence it is provided with location identifying system functions.

Although not shown in Fig. 2, the center station 90 comprises, in addition to the foregoing, the standard functional composition provided in the center station of a conventional mobile communications system (for example, functions for sending and receiving signals to and from base stations and mobile terminals, a function for displaying the location of a specified mobile terminal, functions for sending and receiving to and from a user utilizing location information, and the like).

In physical terms, the center station 90 may be constituted by a dedicated station, or by a generic information processing device. For example, a center station 90 may be achieved by running software specifying various processes, such as respective functions, and the location identifying method according to the present invention, and the like, in an information processing device of generic composition, provided with a processing unit, input means, storage means, and output means.

The base station database 91 may store, at the least, positional information (for example, latitude and longitude) for a base station CS_i in correspondence with the identification ID of the base station, and a base station database of a conventional mobile communications system may be used for same. The database may also store the base station's address, output (effective radiation power), antenna height, propagation characteristics (propagation characteristic parameter α described hereinafter, and the like). Fig. 3(a) shows an example of the data structure of the base station database.

The location identifying means 92 identifies location of the mobile terminal on the basis of the reception level Γ_{io} of the radio wave from the base station CS_i as measured by the mobile terminal 10, and the base station database 91. Below, the processing implemented by the location identifying means 92 is described on the basis of the flowchart in Fig. 4. The respective steps can be implemented in any different order, provided that this does not create contradictions in the processes implemented.

(First example)

At step S100, the approximate positional range of the mobile terminal 10 is set. The approximate positional range indicates the large range in which the mobile terminal 10 may be present, and this approximate positional range may

be set, for example, to the positional registration area (general paging area) of the mobile terminal 10, or the zone or cell managed by the base station which has established a communications circuit with the mobile terminal 10. Moreover, the approximate positional range may also be set to the periphery of a base station where the reception level is at or above a prescribed value.

The approximate positional range may also be set as a three-dimensional region, rather than just a two-dimensional region. Moreover, the method for setting the approximate positional range is not limited to the foregoing, and the shape, breadth, and the like, of the approximate positional range can be determined according to the system design.

At step S101, a plurality of assumed positions X_s (where s = 1 - M; M is the number of assumed positions) are set for a mobile terminals within the aforementioned approximate positional range. A assumed position is a point forming a reference for identifying the location of a mobile terminal 10. One method for setting assumed positions involves, for examples, dividing the approximate positional range into a two-dimensional or three-dimensional mesh (grid) shape, and setting assumed positions at each lattice point thereof. The size of the mesh can be set according to the system design (depending

on a trade-off between location identification accuracy and calculation processing load), and it may conceivably be set to 5 m units, 10 m units, or 100 m units.

The assumed positions may be set by previously dividing the whole zone or cell of each base station into a two-dimensional or three-dimensional mesh shape (grid shape). In this case, at step S101, a plurality of previously set assumed positions X_s in the approximate positional range are selected.

Thereupon, the likelihood calculation processing in steps S102 to S106 is performed for the respective assumed positions X_s set above.

At step S102, a plurality of base stations CS_j are selected from the base stations CS_i and the distance (X_s, CS_j) between the base stations CS_j and the assumed position X_s is calculated with reference to the base station database 91. Here, the manner in which base stations CS_j are selected can be determined according to the system design, for example, a prescribed number (for instance, approximately 1 to 10) base stations can be selected from the base stations CS_i, in order of highest reception level Γ_{io}. On the other hand, it is also possible to adopt a composition wherein all the base stations CS_i for which the reception level Γ_{io} is measured are selected. In principle, the greater the number of base stations selected, the

greater the accuracy with which location can be identified. In the following description, it is supposed that all the base stations CS_i are selected.

In step S103, the average reception level Γ_{im} (X_s, CS_i) from a base station CS_i at a assumed position X_s is calculated on the basis of the distance d (X_s, CS_i) between the base station CS_i and the assumed position X_s. The average reception level Γ_{im} (X_s, CS_i) can be calculated on the basis of the propagation characteristics equation (1) below, assuming that the long section variation follows the Okumura curve.

$$\Gamma_{im}(X_s、CS_i)=A_i-10\alpha_i\times\log(d(X_s、CS_i))\ [dB]\quad(1)$$

Here, A_i is the reception level when the distance is a unit distance (for example, 1m), and α_i is an attenuation coefficient.

The parameter A_i can be determined separately for each base station, on the basis of the effective radiation power, antenna height, and the like, stored in the base station database 91. More precisely, it may also be determined on the basis of the antenna sensitivity of the mobile terminal. It is also possible that the parameter A_i is determined in advance and stored in the base station database as propagation characteristics information, as illustrated in Fig. 3(a) and so on.

The parameter α_i can be predetermined separately for each base station either on the basis of values for the reflection, shielding, and diffraction (hereinafter, called "reflection and the like") of the radio waves obtained by simulation based on the peripheral conditions of the base station (for example, topography, buildings, etc.) with reference to three-dimensional map information, or on the basis of measurement values, or on the basis of both simulation values and measurement values. Desirably, the predetermined value α_i is stored as propagation characteristics information in a base station database, as shown in Fig. 3(a).

Desirably, the parameters A_i and α_i are determined separately for each base station, but a composition wherein common parameter values A, α are used for all the base stations may also be adopted. Moreover, an equation other than an Okumura curve may be used as the propagation characteristics equation, in which case, the parameters are determined according to the equation adopted.

At step S104, the probability density function p_{xs} (Γ_i) indicating the short section variation of the reception level from the base station CS_i at the assumed position X_s (in other words, taking the assumed position X_s as a parameter). p_{xs} (Γ_i) can be calculated from the following equation (2).

$$p_{xs}(\Gamma_i) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left\{-\frac{(\Gamma_i - \Gamma_{im}(X_s, CS_i))^2}{2\sigma^2}\right\} \quad \text{for}$$

$i=1,\cdot\cdot,N$ (2)

Here, as equation (2) reveals, in the present embodiment the short section variation follows the decibel-normal distribution. The element σ in equation (2) corresponds to the standard deviation of the decibel-normal distribution, and whilst this value can be determined according to the system design, it may be taken as 4 – 6 dB.

Equation (2) may also be set by supposing that the short section variation follows another probability distribution.

At step S105, the joint probability density function $jp_{xs}(\Gamma)$ at the assumed position X_s is determined on the basis of the following equation (3), assuming that the variation in the reception level from each base station is independent,

$$jp_{xs}(\Gamma) = p_{xs}(\Gamma_1) \times p_{xs}(\Gamma_2) \times \cdot\cdot \times p_{xs}(\Gamma_N) \quad (3)$$

At step S106, the likelihood values $L_{xs}(\Gamma_{1o}, \Gamma_{2o}, \ldots \Gamma_{No})$ corresponding to the probability distribution specified by the joint probability density function $jp_{xs}(\Gamma)$ are determined for the reception level values $\Gamma_o = (\Gamma_{1o}, \Gamma_{2o}, \ldots \Gamma_{No})$. The likelihood values $L_{xs}(\Gamma_{1o}, \Gamma_{2o}, \ldots$

Γ_{No}) may be calculated on the basis of equation (4) below, using the differential values $\Delta\Gamma$.

$$L_{xs}(\Gamma_{1o},\ \Gamma_{2o},\ \ldots,\ \Gamma_{No}) = \int_{\Gamma=\Gamma_1-\Delta\Gamma}^{\Gamma_1+\Delta\Gamma} p_1(\Gamma)d\Gamma \times \cdot\cdot \times \int_{\Gamma=\Gamma_N-\Delta\Gamma}^{\Gamma_N+\Delta\Gamma} p_N(\Gamma)d\Gamma \quad (4)$$

Here, in equation (4), the elements p_1, …, p_N on the right-hand side correspond to the probability density functions $p_{xs}(\Gamma_1)$, … , $p_{xs}(\Gamma_N)$ indicating short section variation of the reception level from the base station CS_1, …, CS_N at the assumed position X_s.

Since $p_i(\Gamma)$ is a probability density function, each element of the left-hand side of equation (4) forming integration by parts will have a value between 0 and 1, and therefore the likelihood values L_{xs} (Γ_{1o}, Γ_{2o}, … Γ_{No}) represented by the multiple thereof will also have a value between 0 and 1. Moreover, an approximation of the integral values can be obtained by multiplying the probability density value by $2\times\Delta\Gamma$.

After calculating the likelihood L_{xs} (Γ_{1o}, Γ_{2o}, … Γ_{No}) for all the assumed positions set, the sequence proceeds to step S107.

At step S107, the S value from S = 1 – M which has the greatest likelihood L_{xs} (Γ_{1o}, Γ_{2o}, … Γ_{No}) is selected (hereinafter, the selected S is called S*), and X_s* is specified as the estimated location of the mobile terminal.

Since the joint probability density function of each assumed position does not in principle depend on the measured reception level Γ_i, it may be determined in advance.

(Modification 1)

In the first example, the processing is composed in such a manner that a propagation characteristics equation set independently for each base station is used in step S103, in consideration of the differences due to the location conditions of each base station.

However, since the atmospheric conditions, and conditions such as reflection, diffraction, and the like, vary with the time of day, day of the week, and season of the year, and the like, it is conceivable that the propagation characteristics will vary even at the same base station, due to these conditions. And traffic density of car or the like may also affect the propagation characteristics. Moreover, the presence of buildings, or the like, between the respective assumed positions and the base station, and the topographical conditions (geographical conditions) therebetween, and the like, may also affect the propagation characteristics.

Therefore, in this first modification, a composition is adopted wherein a plurality of propagation characteristics parameters α_i (and/or parameters A_i) are

stored in the base station database 91 for each base station, in association with at least one of: time information (for example, the time of day, day of the week, season, or the like), traffic density, assumed position, or the like (see Fig. 5). The respective values of α_i (and/or A_i) can be predetermined separately either on the basis of values for the reflection, and the like, of the radio waves obtained by simulation based on the peripheral conditions of the base station with reference to three-dimensional map information, for example, or on the basis of measurement values for the reception level, or on the basis of both simulation values and measurement values.

Moreover, step S103 in the location identifying means 92 is composed as follows. Namely, at least either time information or traffic information at the time of the estimate is obtained from internal means of the center station 90 or from an external device. The propagation characteristics parameter α_i (and/or A_i) corresponding to the information thus obtained and/or the assumed position X_s is then read out by reference to the base station database 91, and the read out αi (and/or A_i) value is used to determine $\Gamma_{im}(X_s、CS_i)$ on the basis of equation (1). The other steps are the same as in the first example.

In this way, a composition is achieved wherein propagation characteristics can be selected and used in

accordance with the time information (for example, time of day, day of week, season of year, etc.), traffic density, assumed position, and the like, and hence the location identifying accuracy can be further improved.

(Idiosyncrasy points)

Here, when storing the propagation characteristics parameter αi (and/or parameter Ai) with respect to assumed positions in the base station database 91, desirably, idiosyncrasy points as defined below are also selected as assumed positions, in addition to the respective grid points of the mesh dividing the approximate positional range as described above.

An idiosyncrasy point can be understood as a measurement point where the reception level is clearly different to the measurement data of measurement points in the vicinity thereof, when the received measurement data is compared, due to the occurrence of complex radio wave propagation characteristics caused by the effects of conditions, such as the shape of the buildings surrounding the measurement point, and the relative position thereof with respect to the base stations.

In the present invention, a constitution is adopted wherein location is identified by determining the likelihood of measured reception levels, on the basis of probability density functions indicating the short section

variation of the reception level at respective assumed positions, and therefore, by selecting idiosyncrasy points displaying different radio wave propagation characteristics to the surrounding points and a distinctive probability density function, as assumed positions, it is possible to reduce location identification error.

Therefore, in a preferred embodiment of the invention which takes account of idiosyncrasy points, the base station database 91 is created by a database creating method comprising the steps of: storing base station numbers (base station identification ID), base station co-ordinates (positional information for base station CSi), and reception levels obtained previously either by measurement or simulation, or both measurement and simulation, of radio wave propagation at respective points in the service area of each base station, as data, in mutually associated fashion; detecting idiosyncrasy points at which a reception level is measured which is idiosyncratic when compared to the reception level at another nearby point, on the basis of the aforementioned stored data; and storing a propagation characteristics parameter αi (and/or parameter Ai) corresponding to the detected idiosyncrasy points.

The following pattern of idiosyncrasy points can be imagined in the case of an urban landscape, for example. 1)

In the vicinity of gaps between buildings of a prescribed interval (for example, 2 – 3 m); 2) in the vicinity of the boundaries between buildings and local open spaces (open-air parking lot, empty space left by removed building, and the like); 3) in front of a building set further back than nearby buildings; 4) at points affected by shielding or reflection by a high-rise building situated amongst a collection of low buildings; 5) in the vicinity of a low building situated amongst a collection of high-rise buildings; 6) in the vicinity of a large building of irregular shape; 7) at points with good radio transparency compared to nearby points (for example, intersections); 8) buildings made from differing materials (for example, steel and wood, the vicinity of buildings with reflective surface walls, glass-clad and tile-clad structures); and the like.

Below, a method is described for detecting idiosyncrasy points in the aforementioned patterns on the basis of measured reception levels.

In a first pattern, the reception levels were measured at points 304, 107, 108 as illustrated in Fig. 14A. This diagram shows the relative position of buildings and roads when viewed from above at a particular location, in the form of a line diagram, (same applies to Fig. 15, etc. below). At each point, a signal could be received from at least three base stations A-150, A-210, A-270. Fig. 14B shows the reception level received from each of the base

stations at the respective points. Here, since points 304, 107 and 108 are mutually close, in principle, they should display a similar tendency in their reception levels, but in fact the reception level from the base station A-270 at point 304 is a level of 55.1 dBuV/m which is higher than the inferential value of 45 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought to occur because point 304 is located in a gap between buildings, and hence the reception level rises in accordance with the improved radio visibility thereof compared to the other points. According to the method for creating a database according to the present invention, this point 304 is detected as an idiosyncrasy point and the propagation characteristics parameters αi, and the like, at point 304 are stored in order to be used as an assumed position.

In the second pattern, the reception levels were measured at points 308, 175 and 176 as illustrated in Fig. 15A. At each point, a signal could be received from at least three base stations A-330, A-30, A-90. Fig. 15B shows the reception level received from each of the base stations at the respective points. Here, since points 308, 175 and 176 are mutually close, in principle, they should display a similar tendency in their reception levels, but in fact the reception level from the base station A-330 at point 308 is

a level of 39.7 dBuV/m which is lower than the inferential value of 55 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought to occur because point 308 is situated at the border between buildings and an open space, and is therefore shielded by the buildings, thus lowering the reception level thereof.

In the third pattern, the reception levels were measured at points 306, 127 and 128 as illustrated in Fig. 16A. At each point, a signal could be received from at least three base stations A-180, A-240, A-300. Fig. 16B shows the reception level received from each of the base stations at the respective points. Here, since points 306, 127 and 128 are mutually close, in principle, they should display a similar tendency in their reception levels, but in fact the reception level from the base station A-300 at point 306 is a level of 43.4 dBuV/m which is higher than the inferential value of 35-40 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought to occur because point 306 is situated in front of a building which is set back further than neighbouring buildings, and hence the shielding effect is reduced and the reception level is increased.

In the fourth pattern, the reception levels were measured at the points 359, 144 and 145, as shown in Fig. 17A. At each point, a signal could be received from at

least three base stations A-270, A-330, A-30. Fig. 17B shows the reception level received from each of the base stations at the respective points. Here, since points 359, 144 and 145 are relatively close, in principle, they should display a similar tendency in their reception levels, but in fact the reception level from the base station A-30 at point 359 is a level of 78.3 dBuV/m which is higher than the inferential value of 70 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought to occur because at point 359 the radio waves are reflected by the high-rise building amongst the low buildings, and therefore, the reception level is higher than at point 144 directly below the building, or point 145 which is separated from the building.

In the fifth pattern, the reception levels were measured at the points 356, 221 and 224, as illustrated in Fig. 18A. At each point, a signal could be received from at least three base stations A-30, A-90, A-150. Fig. 18B shows the reception level received from each of the base stations at the respective points. Here, since points 356, 221 and 224 are mutually close, in principle, they should display a similar tendency in their reception levels, but in fact the reception level from the base station A-150 at point 356 is a level of 40.4 dBuV/m which is higher than the inferential value of 35 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought

to occur because point 356 is situated in front of a low building located amongst a collection of high-rise buildings, and therefore the shielding effect is reduced and hence the reception level is increased.

In the sixth pattern, the reception levels were measured at the points 346, 29 and 30, as illustrated in Fig. 19A. At each point, a signal could be received from at least three base stations A-30, A-90, A-150. Fig. 19B shows the reception level received from each of the base stations at the respective points. Here, since points 346, 29 and 30 are mutually close, in principle, they should display a similar tendency in their reception levels, but in fact the reception levels from the base stations A-30, A-150 at point 346 are levels of 75.2 dBuV/m and 74.7 dBuV/m which is higher than the inferential value of 70 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought to occur because point 346 is affected by a large-scale building of irregular shape, and hence the reception level is increased.

In the seventh pattern, the reception levels were measured at the points 310, 200 and 201, as illustrated in Fig. 20A. At each point, a signal could be received from at least three base stations A-30, A-90, A-150. Fig. 20B shows the reception level received from each of the base stations at the respective points. Here, since points 310, 200 and 201 are relatively close, in principle, they should display

a similar tendency in their reception levels, but in fact the reception level from the base station A-90 at point 310 is a level of 51.8 dBuV/m which is higher than the inferential value of 47 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought to occur because point 310 is affected by a large-scale building of irregular shape, and hence the reception level is increased.

In the eighth pattern, the reception levels were measured at the points 343, 358 and 6, as illustrated in Fig. 21A. At each point, a signal could be received from at least three base stations A-120, A-180, A-240. Fig. 21B shows the reception level received from each of the base stations at the respective points. Here, since points 343, 358 and 6 are mutually close, in principle, they should display a similar tendency in their reception levels, but in fact the reception level from the base station A-180 at point 343 is a level of 58.3 dBuV/m which is higher than the inferential value of 53 dBuV/m that would be expected from the tendency of the reception level at the other points. This is thought to occur because point 358 is situated in the vicinity of a building of differing materials (building with reflective surface walls), and therefore the reception level increases due to the reflection of the reflective walls).

(Modification 2)

In the first example, the processing was composed in such a manner that a common standard deviation σ (variance σ^2) was used for all base stations CS_i in step S104.

However, the short section variation of the reception level does not necessarily always follow a probability distribution of the same fluctuation and there is a high possibility that the fluctuation will also change if the ambient environment of the base station, or the like, changes.

Therefore, in this second modification, the processing is composed in such a manner that the probability density function $p_{xs}(\Gamma_i)$ is determined using a standard deviation σ_i set separately for each base station, in order to be compatible with cases where the fluctuation of the short section variation is different at each base station.

The standard deviation for each base station can be set according to the system design, but it may also be separately estimated and set in advance, for example, on the basis of simulation values for the reflection, or the like, of the radio waves derived from the ambient environment of the base station with reference to three-dimensional map information, or on basis of measurement values for the short section variation, or on both simulation values and measurement values, in a similar

manner to the propagation characteristics parameter α_i, or the like. The standard deviation thus set is stored in association with the base station in the base station database 91 (see Fig. 3(b)).

In this second embodiment, step S104 implemented by the location identifying means 92 is constituted as follows. The standard deviation σ_i corresponding to the base station CS_i is read out by referring to the base station database 91. Thereupon, the probability density function $p_{xs}(\Gamma_i)$ is determined on the basis of the following equation (5). The other steps are similar to those in the first example.

$$p_{xs}(\Gamma_i) = \frac{1}{\sqrt{2\pi\sigma_i^2}} \exp\left\{-\frac{(\Gamma_i - \Gamma_{im}(X_s, CS_i))^2}{2\sigma_i^2}\right\} \quad \text{for} \quad i=1,\cdot\cdot,N \qquad (5)$$

Similarly to the propagation characteristics parameter α_i in the first modification, a composition may be adopted where a plurality of σ_i values are stored for each base station, in accordance with at least one of: time information, traffic density, assumed position, or the like (see Fig. 6). If a plurality of σ_i values are stored with respect to the assumed positions, desirably, the reception levels are measured using a plurality of reception antennas

simultaneously, and a database is created on the basis of the measured values for short section variation, by dividing the measurements positions at an order of several metres. In this case, by determining the probability density function $p_{xs}(\Gamma_i)$ using values for α_i, and the like, and σ_i which correspond to the assumed position, it is possible to determine a probability density function $p_{xs}(\Gamma_i)$ which takes account of the presence of buildings and the like, or the topographical conditions, between the assumed position and the base station.

In this way, by adopting a composition which uses standard deviation values set separately for each base station, it is possible to improve the location identifying accuracy.

(Modification 3)

In the first example, at step S106, the likelihood $L_{xs}(\Gamma_{1o}, \Gamma_{2o}, \dots \Gamma_{No})$ is determined on the basis of the joint probability density function expressed by the multiple of the probability density function of each base station.

In some cases, depending on the base station, the zone or cell may be divided into a plurality of sectors (for example, 3 sectors of 120° or 6 sectors of 60°) by using directional antennas, in order to increase frequency efficiency and raise the number of channels. By adopting sectoring of this kind, it is possible to allocate limited

channels dynamically to each sector, thereby permitting efficient channel allocation and utilization to a sector where traffic is concentrated, in the case of high traffic conditions. If a base station has a sector composition in this way, then the reception level from the base station will also depend on the angle of orientation of the sector.

Therefore, in this third modification, if the base station has a sector composition, then the processing is composed in such a manner that the likelihood is determined by also taking account of the effects of the angle of orientation of the sectors. More specifically, the step S106 implemented by the location identifying means 92 is composed as follows. A joint probability is determined which is a function of the angular deviation between the line linking the assumed position X_s and the base station, and the angle of orientation of the sector, and this joint probability is multiplied by the L_{xs} $(\Gamma_{1o}, \Gamma_{2o}, \ldots \Gamma_{No})$ values determined according to the first example, the multiplication results being used as the new L_{xs} $(\Gamma_{1o}, \Gamma_{2o}, \ldots \Gamma_{No})$ values. The other steps are the same as those in the first example.

In this way, by adopting a composition wherein the effects of the angle of orientation of the sectors are taken into account when determining the likelihood, it is

possible further to improve the location identifying accuracy.

(Modification 4)

In the first example, at step S107, the assumed position having the greatest likelihood is selected, and this is identified as the position of the mobile terminal.

However, sometimes, it is not necessarily the case that the likelihood of only one assumed position stands out, but rather, similar likelihood values are determined for a plurality of assumed positions. In this case, it can be seen that selecting a plurality of assumed positions having a likelihood which is greater than a prescribed threshold value enables the location to be identified more safely than selecting only the assumed position having the greatest likelihood.

Therefore, in this fourth modification, the step S107 implemented by the location identifying means 92 is composed as follows. A plurality of assumed positions having a likelihood value L_{xs} (Γ_{1o}, Γ_{2o}, ... Γ_{No}) exceeding a prescribed threshold value are selected, an estimated area is determined on the basis of the plurality of assumed positions thus selected, and this estimated area is identified as the location of the mobile terminal 10. The other steps are the same as those in the first example.

Conceivable methods of determining the estimated area include setting the estimated area as the circular region having the smallest radius which encloses all of the plurality of selected assumed positions, for example, or setting the estimate area as a circular region of a prescribed radius centerd on the average position of the plurality of selected assumed positions. When determining the estimated area, desirably, those of the selected assumed positions which are significantly distanced from the average position, or the like, should be excluded.

(Experimental results)

The results of applying the location identifying method according to the present invention are described below. Here, it was assumed that due to multi-path effects in the mobile terminal, three waves are observed simultaneously for each measurement, the average value of the three observation values being used as the measurement value.

(Simulation results 1)

The likelihood distribution was found by performing a simulation of the location identifying method of the present invention under the following conditions.

(1) The propagation characteristics parameters were taken as common characteristics for all the base stations, with values of $A = 130$ and $\alpha = 3.4$.

(2) The short section variation was assumed to follow decibel-normal distribution, and the standard deviation thereof was taken as common for all base stations, having a value of $\alpha = 6$(dB).

(3) The base stations were located according to a cellular model, the cell radius being 500(m), and the number of base stations being 19 (see Fig. 7).

(4) The mobile terminal was positioned in the middle of the central cell.

(5) The approximate positional range set in step S100 was taken to be the central cell.

Fig. 8 shows the likelihood distribution determined according to the present invention in a case where 1 – 3 base stations are selected as base stations CS_j. In the diagram, BS indicates a base station and MS indicates the mobile terminal, the height of the three-dimensional graph indicating the likelihood. From the diagram, it can be seen that the tendency for the likelihood distribution to be skewed increases as the number of base stations increases. This signifies that there is a greater possibility of the being able to identify the location of the mobile terminal more precisely, the greater the number of base stations. If the assumed position having the greatest likelihood was taken as the estimated position of the mobile terminal,

then in the case of three base stations, an estimation error of 11(m) resulted.

(Simulation results 2)

The estimation error was found by performing a simulation of the location identifying method of the present invention under the following conditions.

(1) The propagation characteristics parameters were taken as common characteristics for all the base stations, with values of $A = 130$ and $\alpha = 3.4$.

(2) The short section variation was assumed to follow decibel-normal distribution, and the standard deviation thereof was taken as α=6(dB) for all base stations in case 1, and α = 6(dB) for the central cell only, and α=4(dB) for the other cells, in case 2.

(3) The base stations are located according to a cellular model, the cell radius being 500(m), and the number of base stations being 19.

(4) The mobile terminal was positioned in the central cell according to a uniform distribution, and 500 sets of measurement data were generated.

(5) The approximate positional range set in step S100 was taken to be the central cell.

Fig. 9 shows the estimation error in case 1 and case 2, when 3 - 10 base stations were selected as the base stations CS_j. Here, the estimation error is the estimation

error at a point where the cumulative probability is 0.67. From the diagram, it can be seen that the greater the number of base stations, the greater the accuracy with which the location can be identified, and by setting the σ value to a lower value in the cells other than the central cell, the accuracy with which the location can be identified becomes greater.

(Simulation results 3)

Simulations of the location identifying method according to the present invention and an SX method were performed under the following conditions, and the estimation error was compared.

(1) The propagation characteristics parameters were taken as common characteristics for all the base stations, with values of $A = 130$ and $\alpha = 3.4$.

(2) The short section variation was assumed to follow decibel-normal distribution, and the standard deviation thereof was taken as common for all base stations, having a value of $\alpha = 6$(dB).

(3) The base stations were located according to a cellular model, the cell radius being 500(m), and the number of base stations being 19 (see Fig. 7).

(4) The mobile terminal was positioned in the central cell according to a uniform distribution, and 500 sets of measurement data were generated.

(5) The approximate positional range set in step S100 was taken to be the central cell.

Fig. 10 shows the estimation error for each method in a case where 3 to 10 base stations are selected as base stations CS_j. Here, the estimation error is the estimation error at a point where the cumulative probability is 0.67. Moreover, Fig. 11 shows the relationship between the estimation error and cumulative probability for each method in a case where three or four base stations are selected as base stations CS_j. From these diagrams, it can be seen that the location identifying method according to the present invention enables location to be identified to a greater degree of accuracy than an SX method.

(Results based on measurement values)

Here, the results of applying the location identifying method of the present invention and a conventional method which does not hypothesize probability distribution are presented, on the basis of data measured under the following conditions.

(1) Measurement date : 11th May 2001

(2) Measurement location : 45 locations in the vicinity of Hon-machi, Chuo-ku, Osaka.

(3) Measurement details : The reception level of the radio waves from surrounding base stations was measured, in a total of 448 measurements (approximately 10 at each location).

Fig. 12 shows the relationship between the estimation error and cumulative probability for each method, in a case where three base stations are selected as base stations CS_j. Moreover, Fig. 13 shows the details of the results of the location identifying method according to the present invention. From the diagrams, it can be seen that, in terms of measurement data also, the location identifying method according to the present invention enables location to be identified to a higher degree of accuracy that a conventional method.

(Second embodiment)

Next, a second embodiment of the present invention will be described. The second embodiment comprises a storage medium for storing a location identifying program. A CD-ROM, magnetic disk, semiconductor memory, or other medium may be used for this storage medium.
The location identifying program is read from the storage medium into the data processing device, and control the operation of the data processing device. Under the control of the location detecting program, the data processing device executes, at the least, the same processing as that of the location identifying means 92 of the center station 90 in the first embodiment.

(Other embodiments)

The present invention is not limited to the embodiments described above, and may also be applied in

various modifications. For example, in the foregoing embodiment, a composition was adopted wherein the reception level of radio waves from the base stations is measured at the mobile terminal 10, but it is also possible to adopt a composition wherein the reception level of radio waves from the mobile terminal is measured at the base stations. In this case, the parameters A and α, and the standard deviation σ of the short section variation, and the like, are determined in accordance with the functional composition of the mobile terminal.

Moreover, in the foregoing embodiment, a composition was adopted wherein the likelihood was calculated on the basis of the reception level, but a composition may also be adopted wherein the likelihood is calculated on the basis of the propagation delay time, instead of the reception level.

Furthermore, in the foregoing embodiment, for example, the location of the mobile terminal was detected in the center station, but it is also possible to adopt a composition wherein the detection processing is carried out in the mobile terminal (or base station). In this case, the mobile terminal (or base station) may comprise a base station database, or at the least, be composed in such a manner that it can access a base station database.

According to the present invention, since a probability distribution is hypothesized for the short section variation of the reception level of radio waves from base stations, at respective assumed positions, a likelihood corresponding to a measurement value of the reception level as measured by the mobile terminal is determined on the basis of the probability distribution, and the assumed position having the greatest likelihood value is specified as the location of the mobile terminal, it is possible to determine the location of the mobile terminal as a maximum likelihood estimate value, based on the assumption that the short section variation follows the probability distribution.

Moreover, since the location identifying accuracy can be raised by setting a small mesh size, whereas the number of assumed positions to be processed can be reduced, thereby reducing the calculational load, by setting a large mesh size, it is possible to achieve flexible control with respect to a trade-off between calculational load and positional accuracy, by adjusting the mesh size.

The entire disclosure of Japanese Patent Application No.2001-270217 filed on September 6, 2001 including specification, claims, drawings and summary are incorporated herein by reference in its entirety.

CLAIMS

1. A location detecting method for a mobile communications system constituted by a plurality of base stations, a mobile terminal and a control station, in which signals are sent by the base stations, numbers unique to each base station being included in the signals from said base stations, the mobile terminal receives said signals from one or a plurality of N base stations, the reception level Γ_i from the i^{th} base station thereof is measured and stored, the 1^{st} to N^{th} reception levels are transferred to the control station via communicating base stations, and at the control station, the location of the mobile terminal is identified on the basis of a database created on the basis of the base station numbers, base station co-ordinates, and reception levels obtained previously either by measurement or radio wave propagation simulation, or both measurement and simulation, at respective points in the service area of each base station, and the reception levels sent by the mobile terminal, said location detecting method bding characterized in that it comprises the steps of:

setting co-ordinate points of a two-dimensional or three-dimensional mesh shape or grid shape, across the whole service area of each base station;

determining an estimate value for the average reception level, corresponding to each base station having

received said signals (hereinafter, called "signal receiving base station"), at each candidate point from among said co-ordinate points, and taking said estimate value as an average value and determining the probability density function of the variation of said average value,

integrating said probability density functions determined for said candidate points, for a given range, on the basis of said measured reception levels, for each signal receiving base station, at each of said candidate points;

determining the likelihood of the candidate points by multiplying together the values obtained by said integration for each signal receiving base station, at each of said candidate points; and

detecting the candidate point having the greatest likelihood value as an estimated location of the mobile terminal.

2. The location detecting method according to claim 1, characterized in comprising the steps of:

determining an estimate value of the average reception level, corresponding to each base station having received said signals (hereinafter, called "signal receiving base station"), at each candidate point from among said co-ordinate points, and taking said estimate

value as an average value and determining the probability density function of the variation of said average value;

substituting said measured reception levels into said probability density function determined for each candidate point, on the basis of said reception levels measured for each signal receiving base station at each candidate point;

determining the likelihood of said candidate points by multiplying together the values obtained by said substitution for each signal receiving base station, at each of said candidate points; and

detecting the candidate point having the greatest likelihood value as the estimated location of the mobile terminal.

3. The location detecting method according to claim 2, characterized in comprising the steps of:

determining an estimate value of the average reception level, corresponding to each base station having received said signals (hereinafter, called "signal receiving base station"), at each candidate point from among said co-ordinate points, and taking said estimate value as an average value and determining the probability density function of the variation of said average value;

substituting measurement data into said probability density function determined for each candidate point, on the basis of said reception levels measured for each signal

receiving base station at each candidate point, and multiplying the value thus obtained by a prescribed value;

determining the likelihood of said candidate point by multiplying together the values obtained by said substitution for each signal receiving base station, at each of said candidate points; and

detecting the candidate point having the greatest likelihood value as the estimated location of the mobile terminal.

4. The location detecting method according to claim 1, characterized in that the likelihood is calculated by estimating parameters relating to the probability density function and propagation characteristics equation for each corresponding base station, individually.

5. The location detecting method according to claim 1, characterized in that the likelihood is calculated by estimating parameters relating to the probability density function and propagation characteristics equation for each mesh, or each grid point, individually.

6. The location detecting method according to claim 1, characterized in that the likelihood is calculated using a propagation characteristics equation having different probability density functions according to the time of day,

day of the week, season of the year, traffic density, or the like, in cases where propagation characteristics taking account of buildings, and topographical conditions, or the like, are expected.

7. The location detecting method according to claim 1, characterized in that, in cases where the base stations have a sector composition, the co-ordinates and the angle of orientation of the sector are linked, a joint probability is set which factors in the difference between each sector angle of orientation, and the likelihood is determined by multiplying said joint probability by the likelihood value corresponding to said co-ordinates.

8. The location detecting method according to claim 1, characterized in that a long section propagation estimate equation and a short section average probability density are determined according to building information or map information, from propagation characteristics which take account of buildings or topographical conditions between said co-ordinates and the base stations.

9. The location detecting method according to claim 1, characterized in that a plurality of estimate locations in which the likelihood is greater than a certain prescribed value are detected as an estimate area.

10. The location detecting method according to claim 1, characterized in that the propagation delay time is used instead of the reception level.

11. A computer-readable storage medium storing a location detecting program for causing a computer to execute the location detecting method according to claim 1.

12. A location detecting program for causing a computer to execute the location detecting method according to claim 1.

13. A method for creating a database used for detecting the position of a mobile terminal in a mobile communications system constituted by a plurality of base stations, a mobile terminal and a control station, characterized in that it comprises the steps of:

storing base station numbers, base station co-ordinates, and reception levels obtained previously either by measurement or radio wave propagation simulation, or both measurement and simulation, at respective points in the service area of each base station, as data, in mutually associated fashion;

detecting idiosyncrasy points at which a reception level is measured that is peculiar when compared to the

reception level at other nearby points, on the basis of said stored data; and

storing the propagation characteristics parameters corresponding to said detected idiosyncrasy points.

14. A method for creating a database used for detecting the position of a mobile terminal in a mobile communications system constituted by a plurality of base stations, a mobile terminal and a control station, characterized in that, in order to determine the standard deviation which is one parameter of the probability density function, a plurality of reception antennas are used and measured simultaneously, and a database is created by identifying measurement positions by the order of several metres.

FIG.1

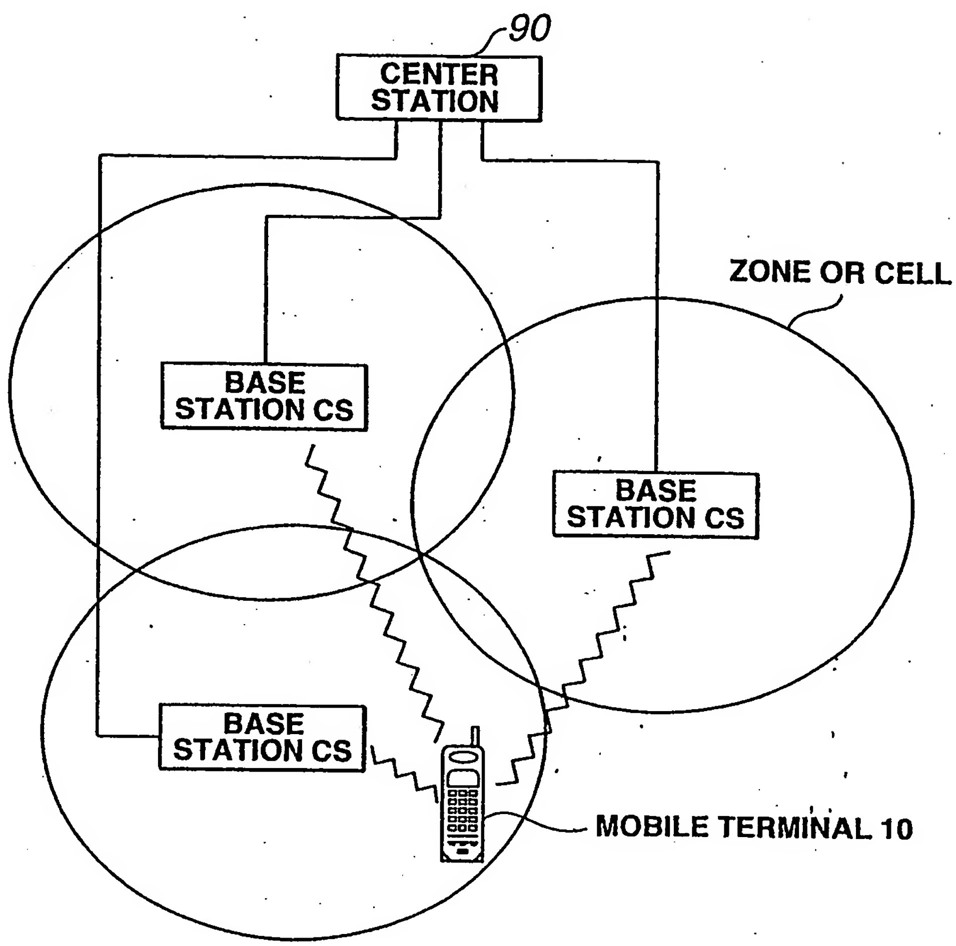

90
CENTER STATION
ZONE OR CELL
BASE STATION CS
BASE STATION CS
BASE STATION CS
MOBILE TERMINAL 10

FIG.2

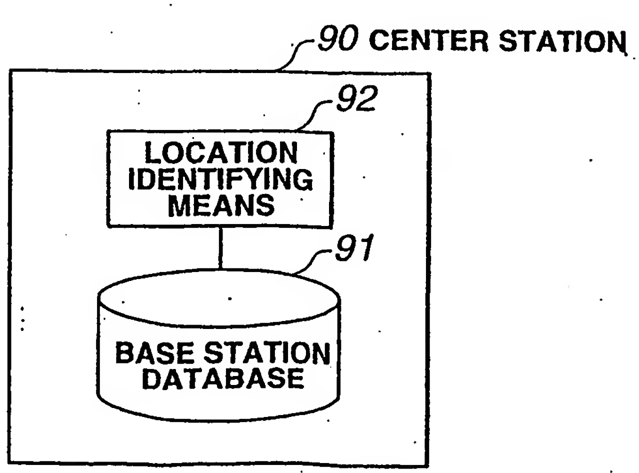

90 CENTER STATION
92
LOCATION IDENTIFYING MEANS
91
BASE STATION DATABASE

FIG.3A

BASE STATION IDENTIFICATION ID	LONGITUDE	LATITUDE	ADDRESS	EFFECTIVE RADIATION POWER	ANTENNA HEIGHT	PROPAGATION CHARACTERISTICS INFORMATION (A, α)

FIG.3B

BASE STATION IDENTIFICATION ID	LONGITUDE	LATITUDE	ADDRESS	EFFECTIVE RADIATION POWER	ANTENNA HEIGHT	PROPAGATION CHARACTERISTICS INFORMATION (A, α, σ)

FIG.4

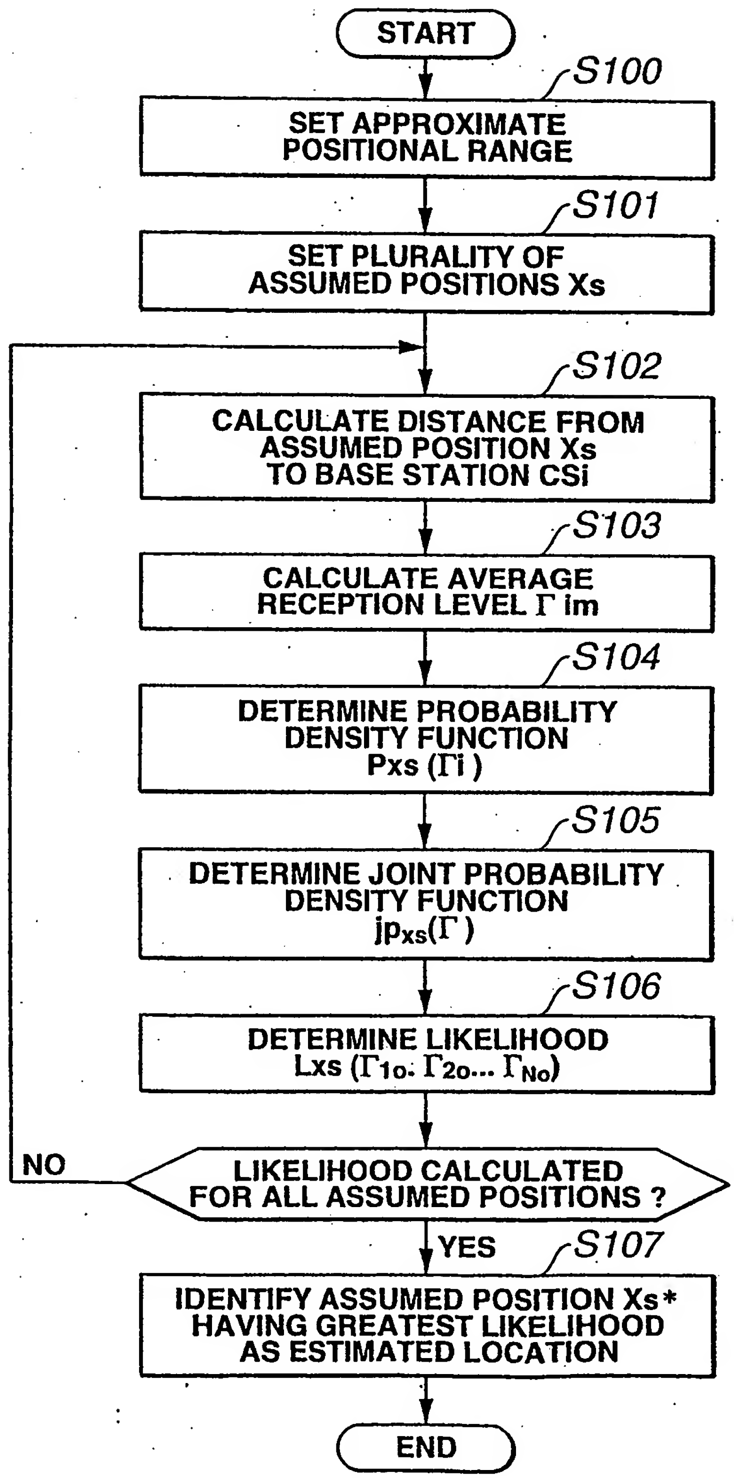

START
S100
SET APPROXIMATE POSITIONAL RANGE
S101
SET PLURALITY OF ASSUMED POSITIONS Xs
S102
CALCULATE DISTANCE FROM ASSUMED POSITION Xs TO BASE STATION CSi
S103
CALCULATE AVERAGE RECEPTION LEVEL Γ im
S104
DETERMINE PROBABILITY DENSITY FUNCTION Pxs (Γi)
S105
DETERMINE JOINT PROBABILITY DENSITY FUNCTION jpxs(Γ)
S106
DETERMINE LIKELIHOOD Lxs (Γ1o, Γ2o... ΓNo)
LIKELIHOOD CALCULATED FOR ALL ASSUMED POSITIONS ?
NO
YES
S107
IDENTIFY ASSUMED POSITION Xs* HAVING GREATEST LIKELIHOOD AS ESTIMATED LOCATION
END

FIG.5

BASE STATION IDENTIFICATION ID	LONGITUDE	LATITUDE	ADDRESS	EFFECTIVE RADIATION POWER	ANTENNA HEIGHT	PROPAGATION CHARACTERISTICS INFORMATION (A, α)

ASSUMED POSITION	TIME INFORMATION		TRAFFIC DENSITY	(A, α)
	SEASON/DAY	TIME		
X_1	REST DAY	A.M.	LOW	
			HIGH	
		P.M.	LOW	
			HIGH	
	WORKING DAY	A.M.	LOW	
			HIGH	
		P.M.	LOW	
			HIGH	
X_2	REST DAY	A.M.	LOW	
			HIGH	
		P.M.	LOW	
			HIGH	
	WORKING DAY	A.M.	LOW	

FIG.6

BASE STATION IDENTIFICATION ID	LONGITUDE	LATITUDE	ADDRESS	EFFECTIVE RADIATION POWER	ANTENNA HEIGHT	PROPAGATION CHARACTERISTICS INFORMATION (A, α, σ)

ASSUMED POSITION	TIME INFORMATION		TRAFFIC DENSITY	(A, α, σ)
	SEASON/DAY	TIME		
X_1	REST DAY	A.M.	LOW	
			HIGH	
		P.M.	LOW	
			HIGH	
	WORKING DAY	A.M.	LOW	
			HIGH	
		P.M.	LOW	
			HIGH	
X_2	REST DAY	A.M.	LOW	
			HIGH	
		P.M.	LOW	
			HIGH	
	WORKING DAY	A.M.	LOW	

FIG.7

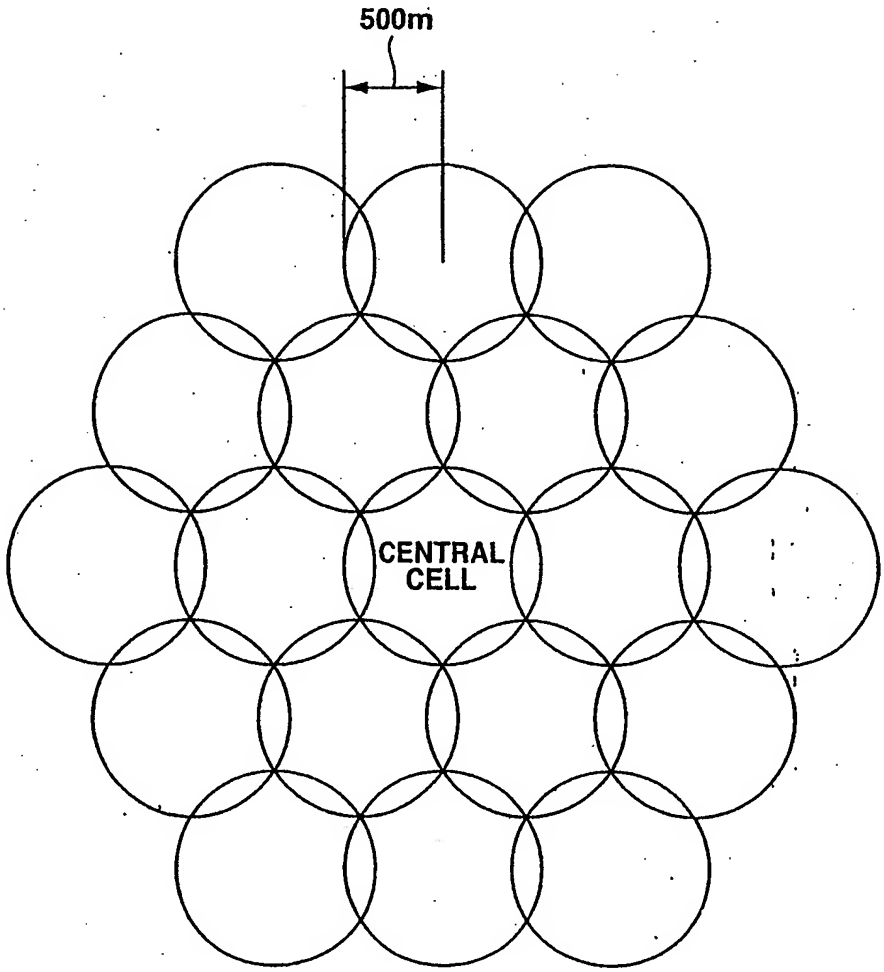


FIG.8A

NUMBER OF BASE STATIONS =1

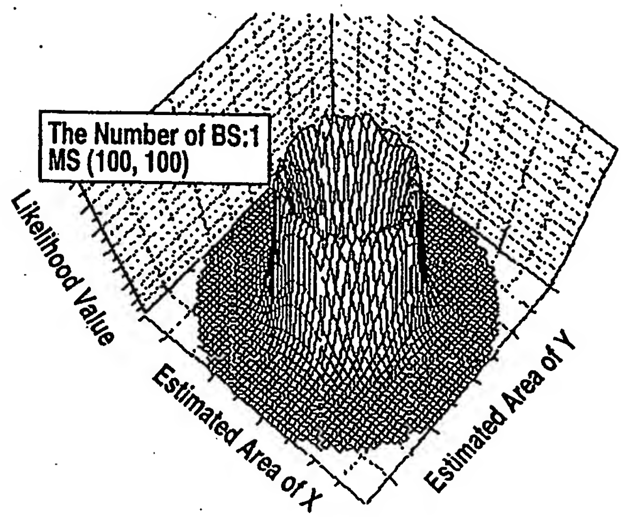


FIG.8B

NUMBER OF BASE STATIONS =2

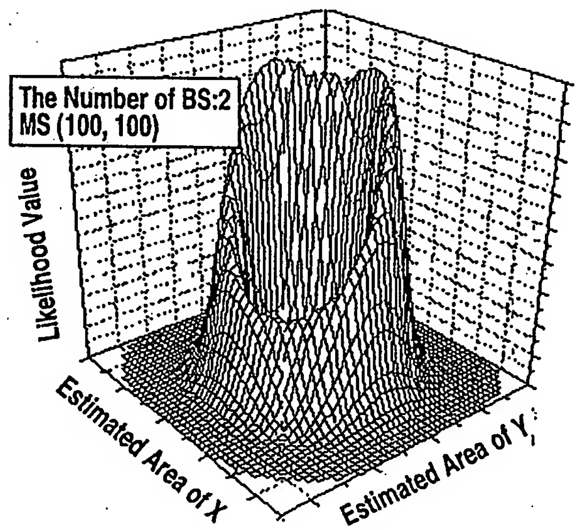


FIG.8C

NUMBER OF BASE STATIONS =3

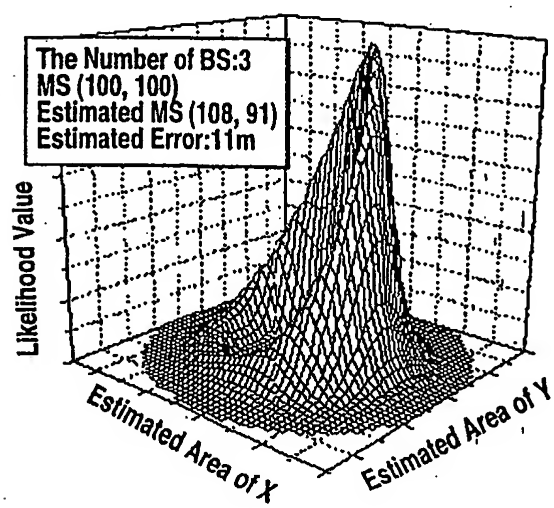


FIG.9

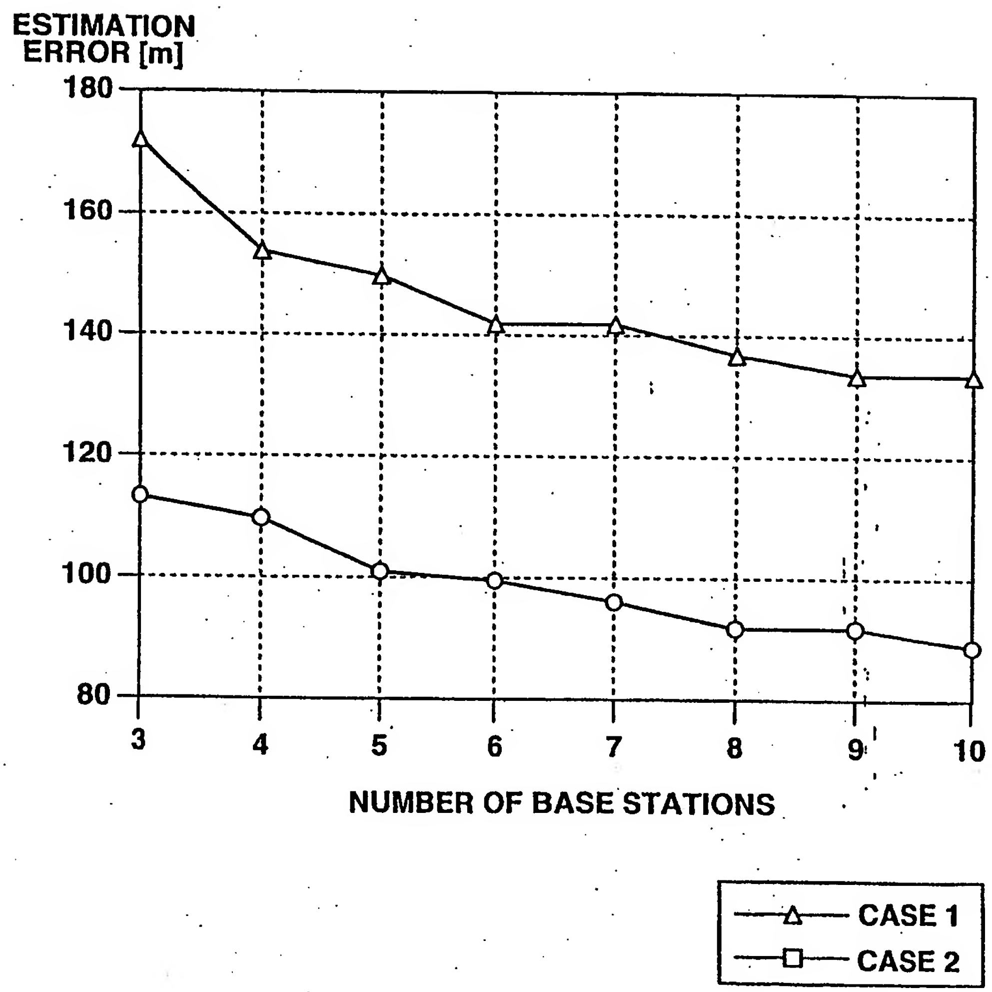

ESTIMATION
ERROR [m]
180
160
140
120
100
80
3
4
5
6
7
8
9
10
NUMBER OF BASE STATIONS
CASE 1
CASE 2

FIG.10

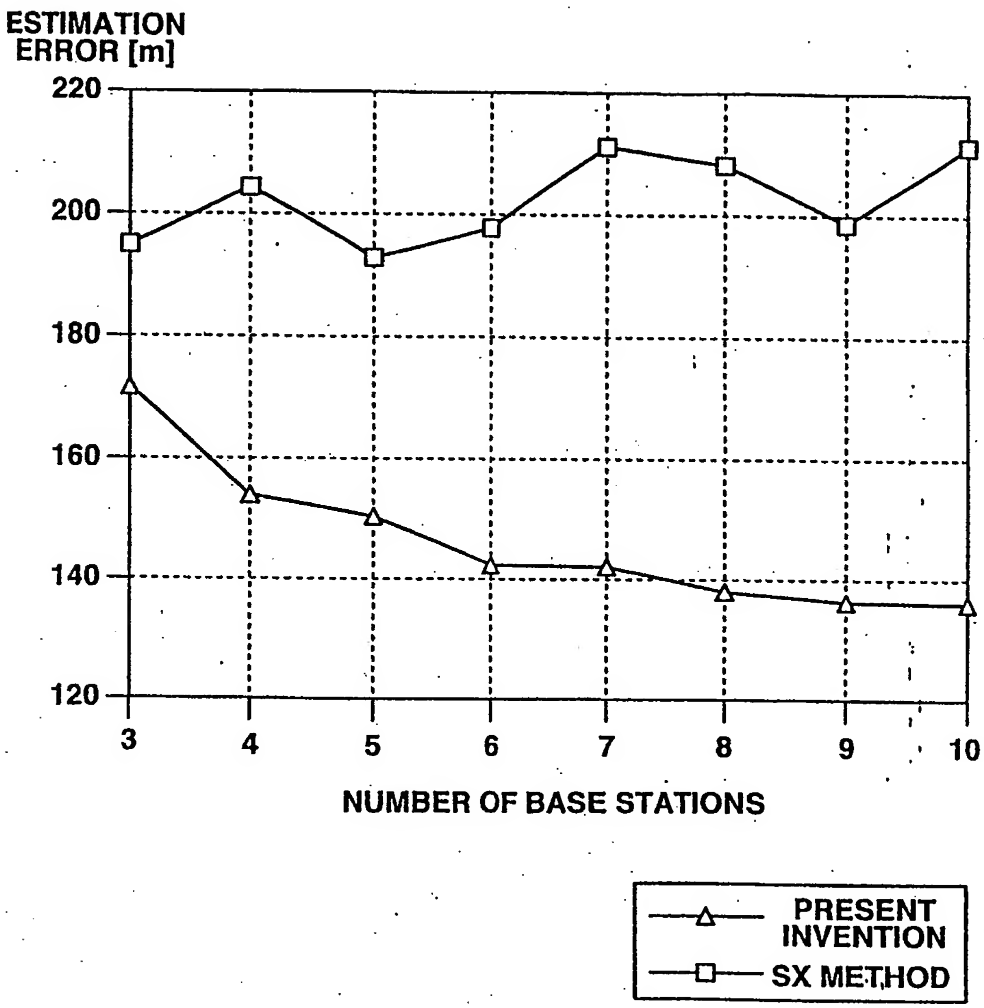
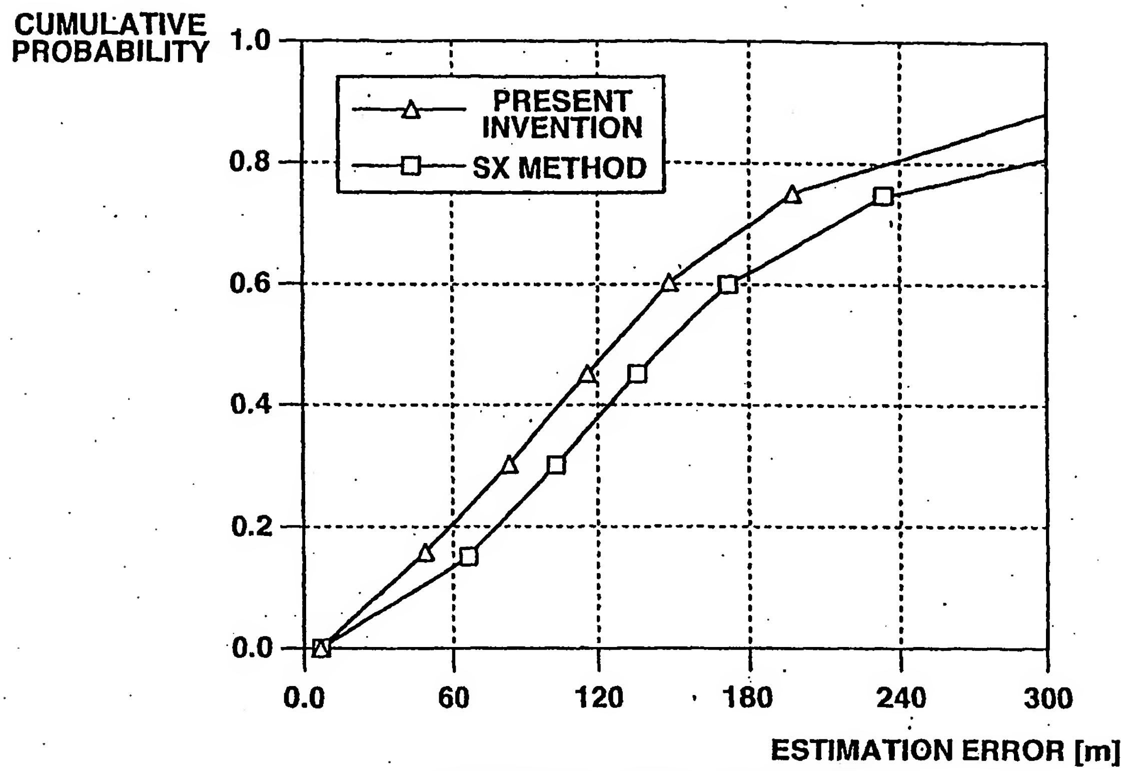
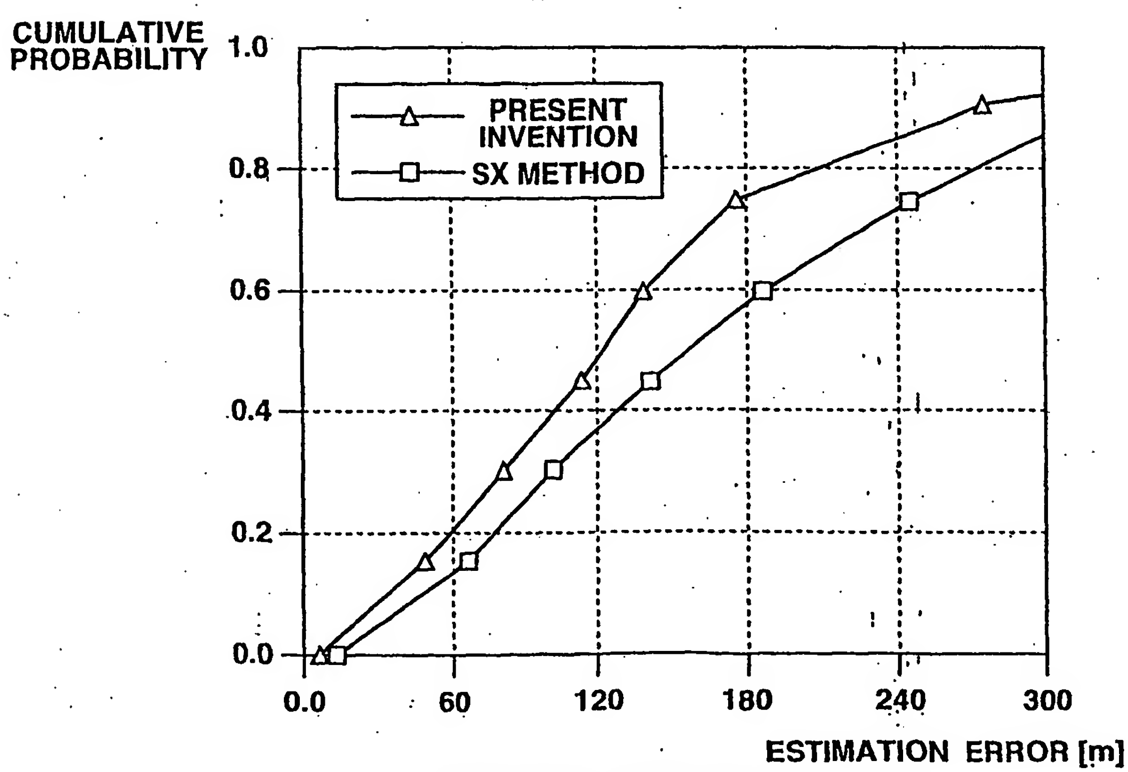

ESTIMATION
ERROR [m]
220
200
180
160
140
120
3
4
5
6
7
8
9
10
NUMBER OF BASE STATIONS
PRESENT
INVENTION
SX METHOD

FIG.11A



NUMBER OF BASE STATIONS =3

FIG.11B



NUMBER OF BASE STATIONS =4

FIG.12

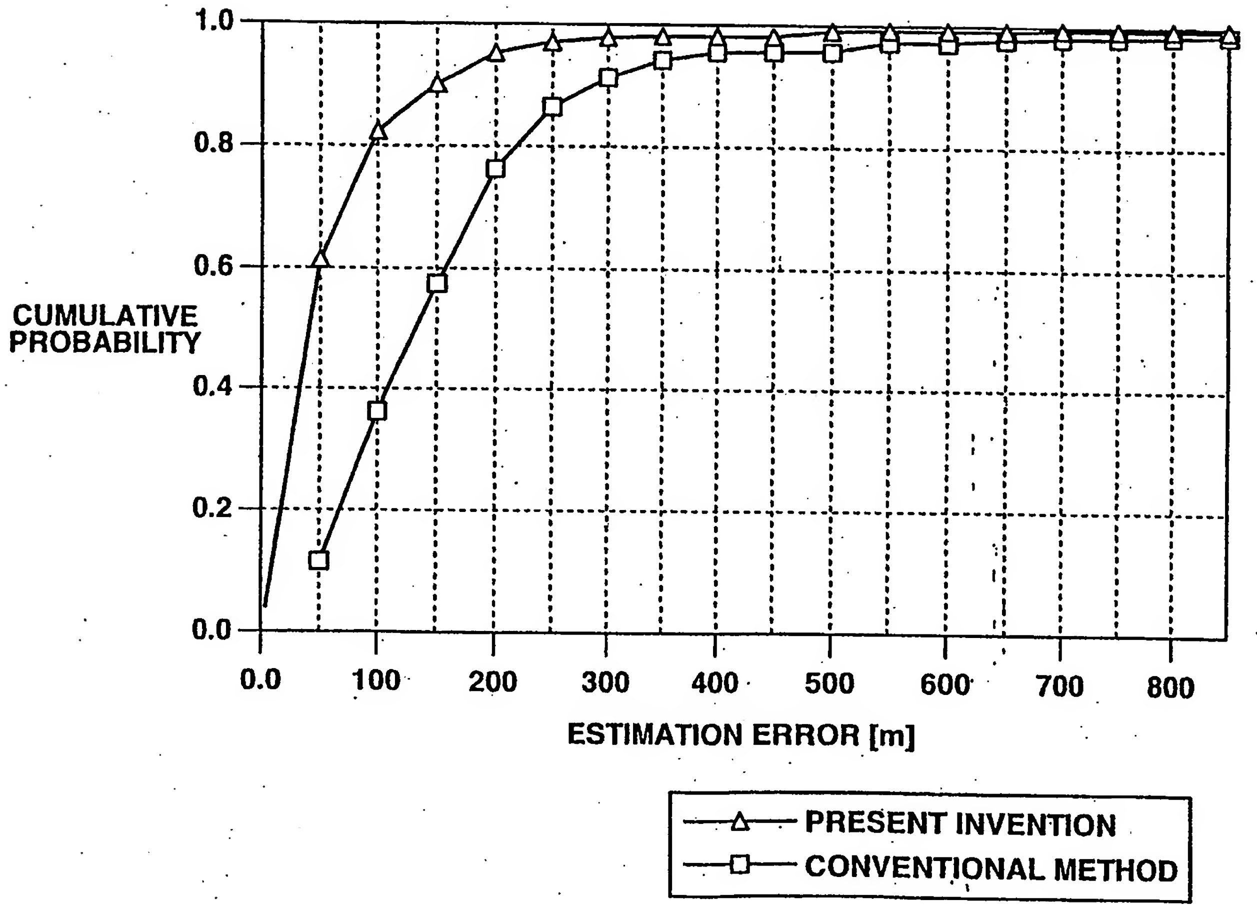

1.0
0.8
0.6
0.4
0.2
0.0
CUMULATIVE PROBABILITY
0.0
100
200
300
400
500
600
700
800
ESTIMATION ERROR [m]
PRESENT INVENTION
CONVENTIONAL METHOD

FIG.13

ESTIMATION ERROR (M)	WITHIN 5M	WITHIN 10M	WITHIN 15M	WITHIN 20M	WITHIN 25M	WITHIN 30M	WITHIN 35M
CUMULATIVE PROBABILITY (%)	2.9	6.9	11.6	19.4	25.4	35.5	43.3

ESTIMATION ERROR (M)	WITHIN 40M	WITHIN 45M	WITHIN 50M	WITHIN 100M	WITHIN 150M	WITHIN 200M	WITHIN 250M
CUMULATIVE PROBABILITY (%)	48.4	57.1	61.2	81.5	90.0	94.2	96.2

ESTIMATION ERROR (M)	WITHIN 300M	WITHIN 350M	WITHIN 400M	WITHIN 450M	WITHIN 500M	WITHIN 550M	WITHIN 600M
CUMULATIVE PROBABILITY (%)	97.3	98.0	98.2	98.7	98.9	98.9	99.1

ESTIMATION ERROR (M)	WITHIN 650M	WITHIN 700M	WITHIN 750M	WITHIN 800M	WITHIN 850M	WITHIN 900M	WITHIN 1450M
CUMULATIVE PROBABILITY (%)	99.6	99.6	99.8	99.8	99.8	99.8	100

FIG.14A

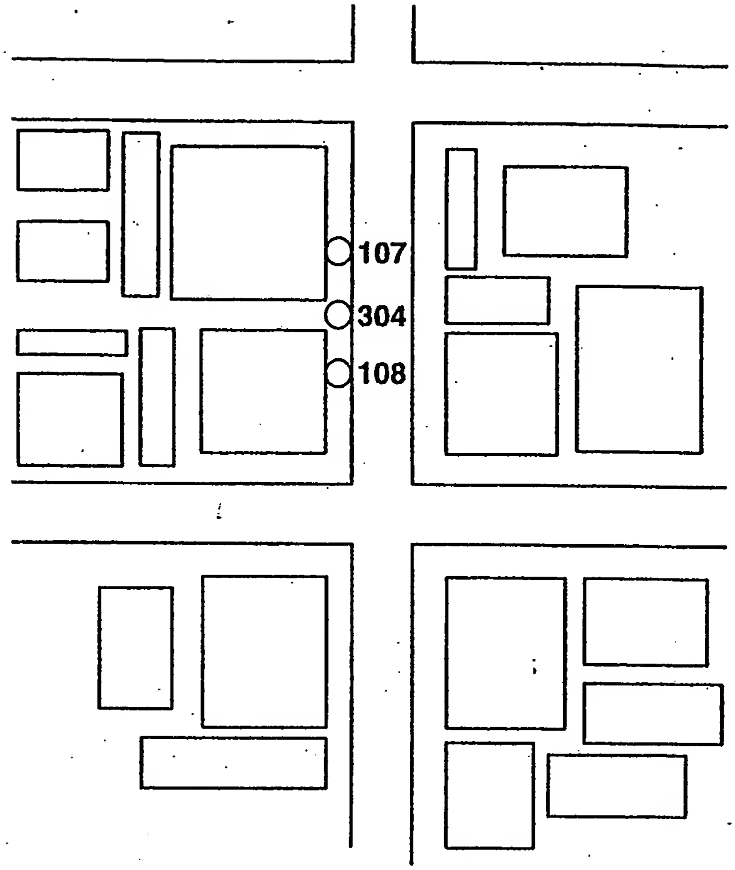


FIG.14B

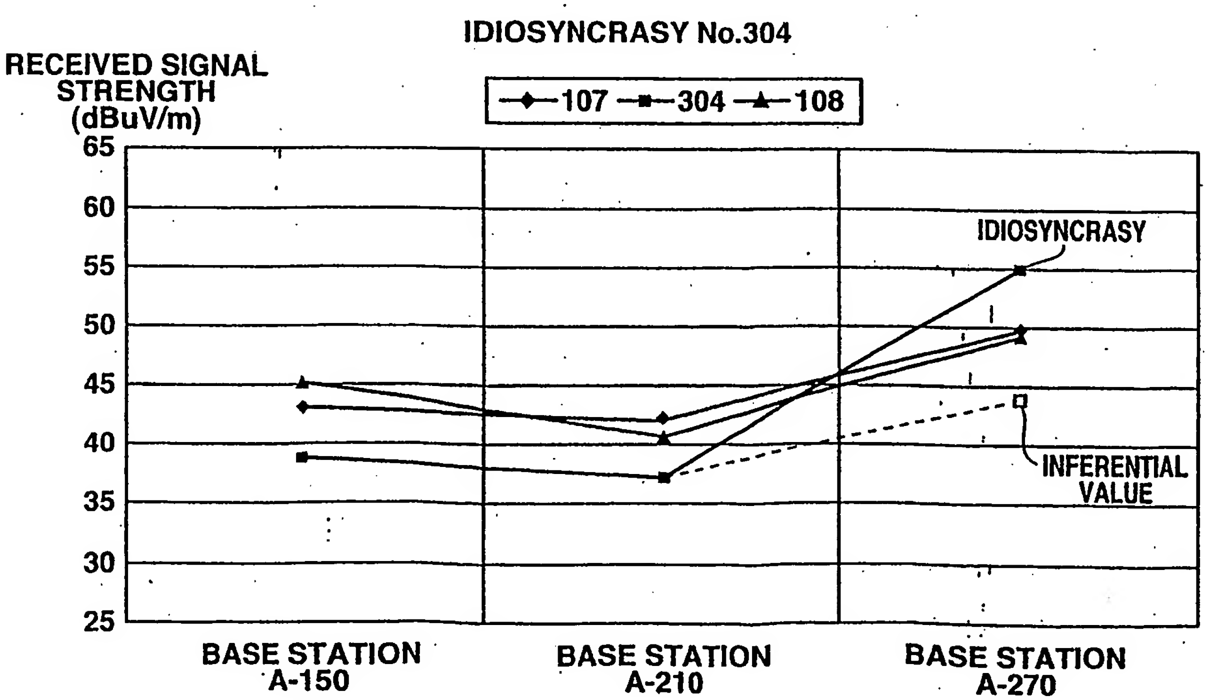


FIG.15A

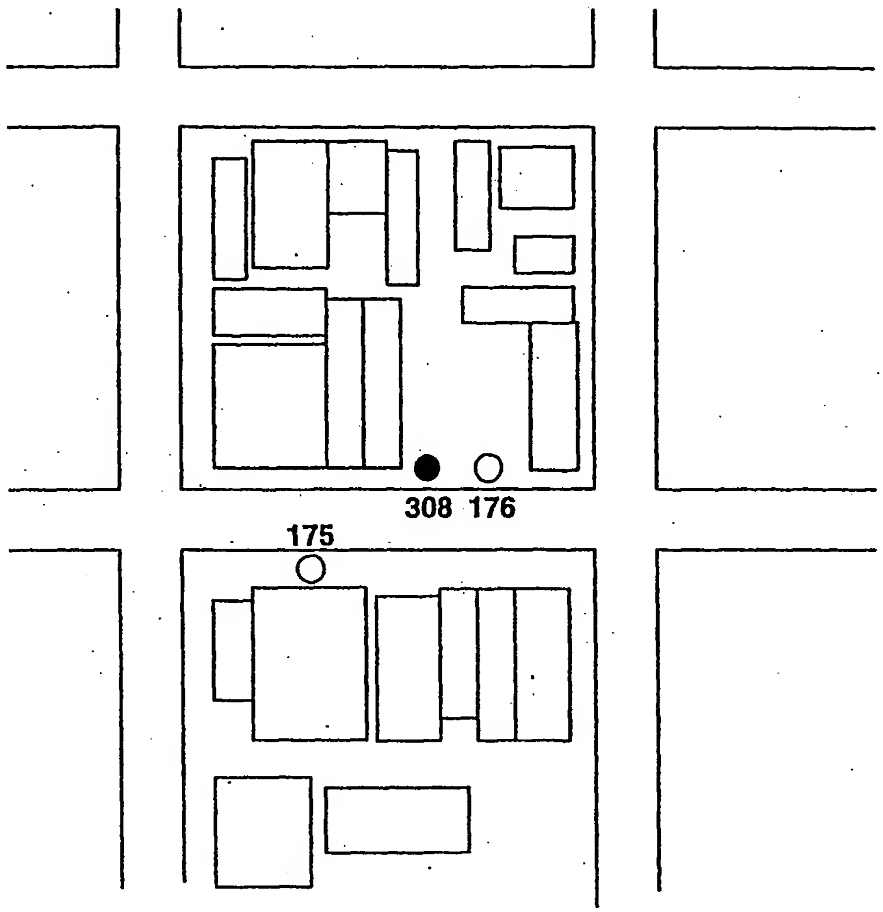


FIG.15B

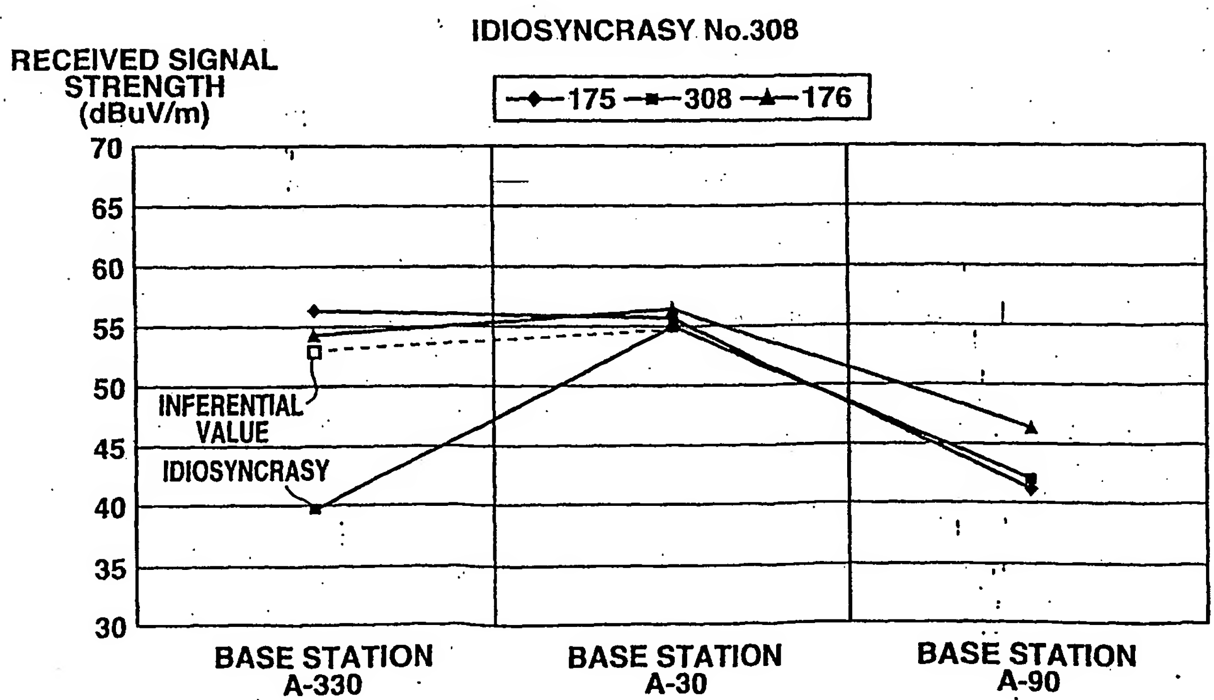


FIG.16A

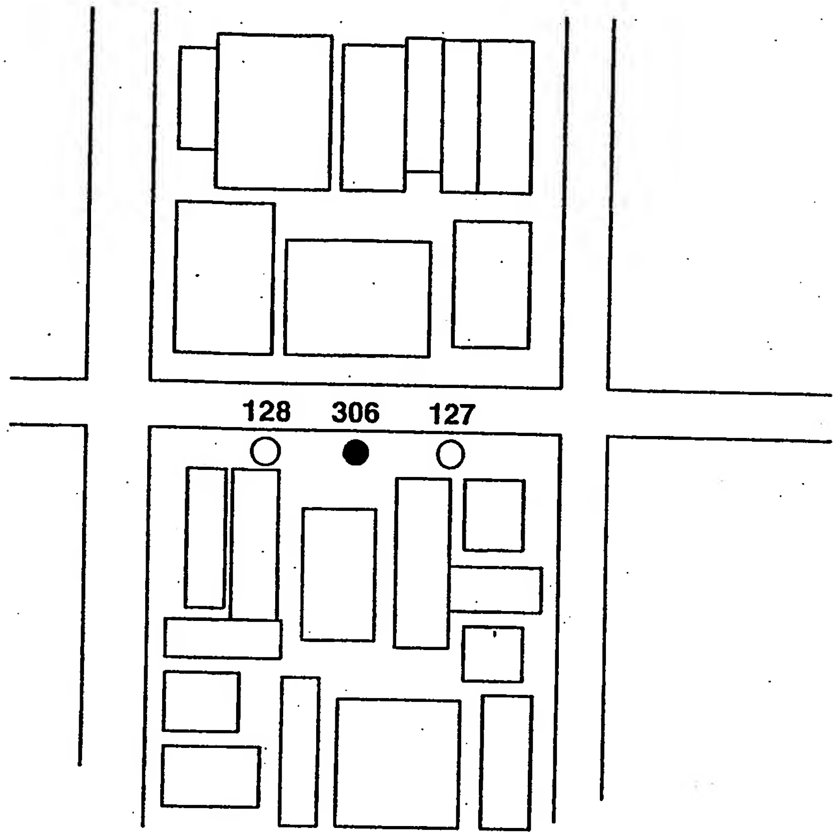


FIG.16B

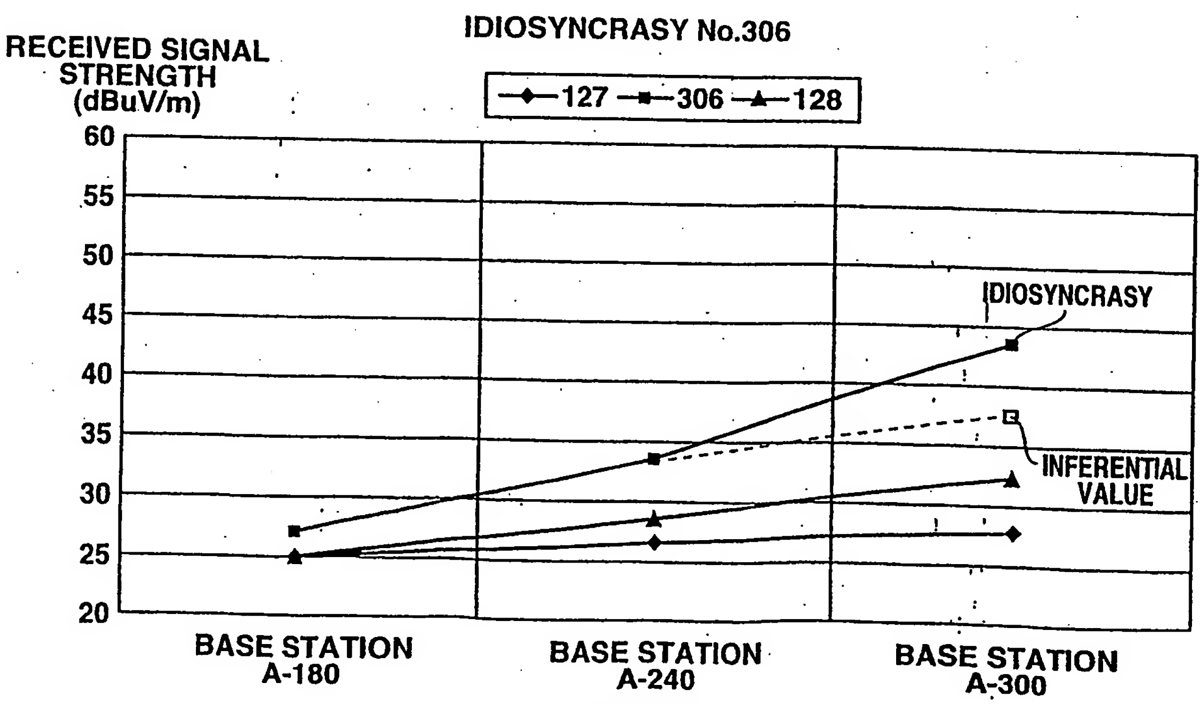


FIG.17A

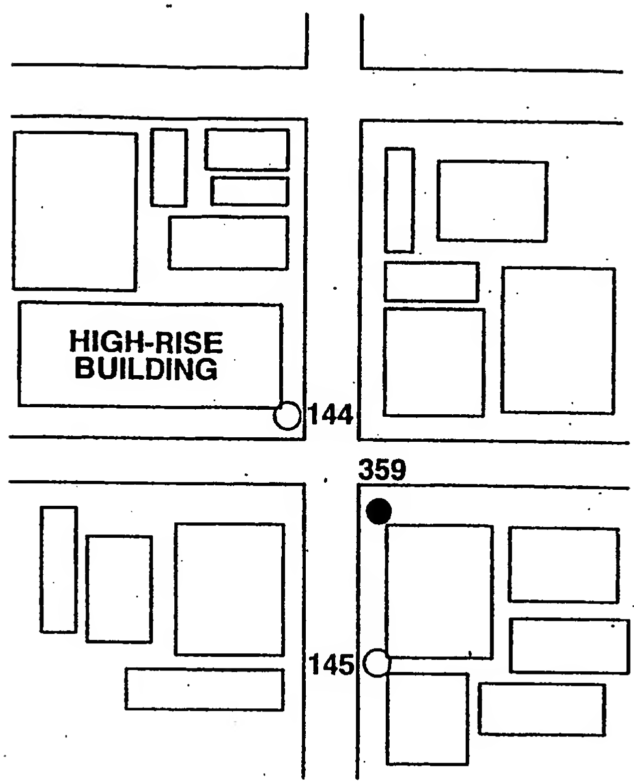


FIG.17B

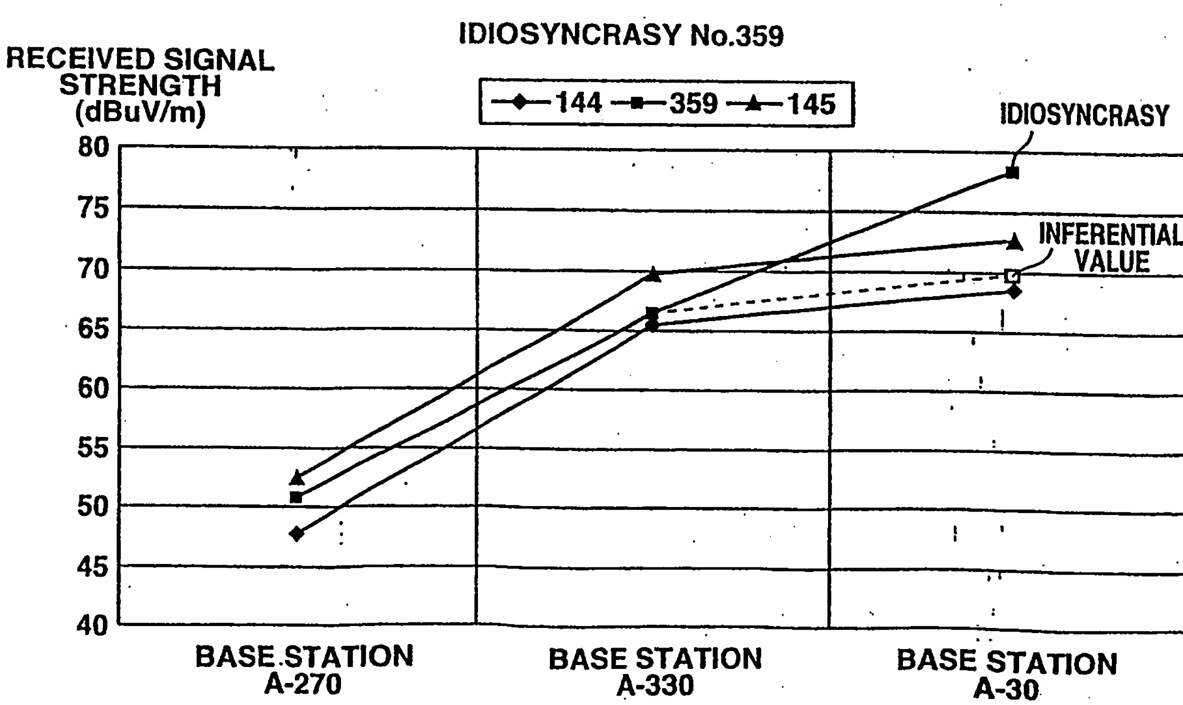


FIG.18A

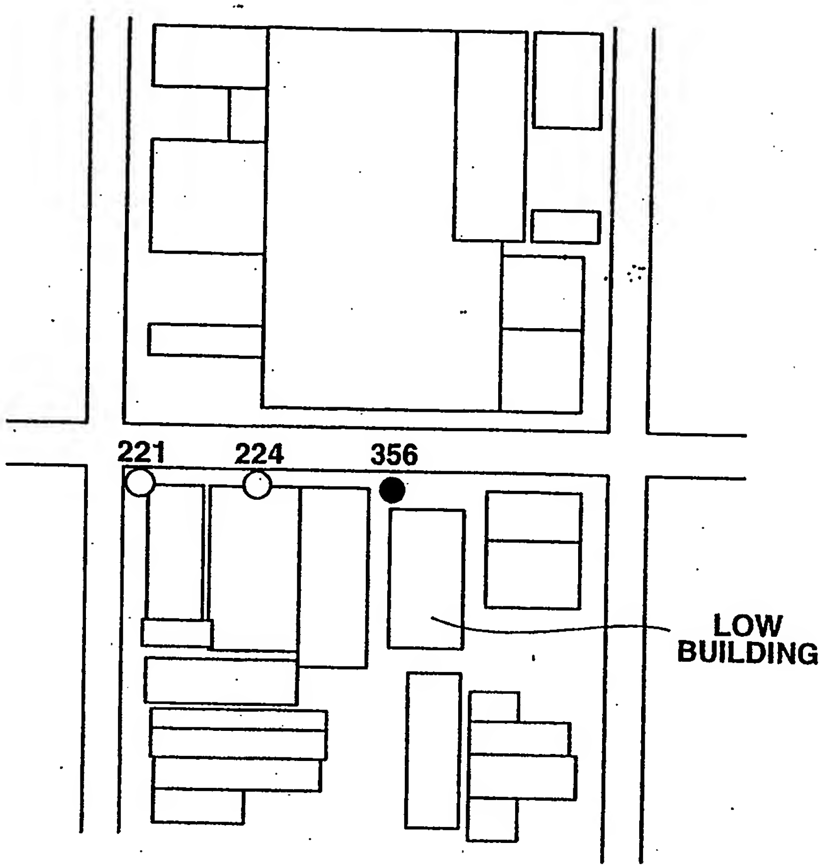


FIG.18B

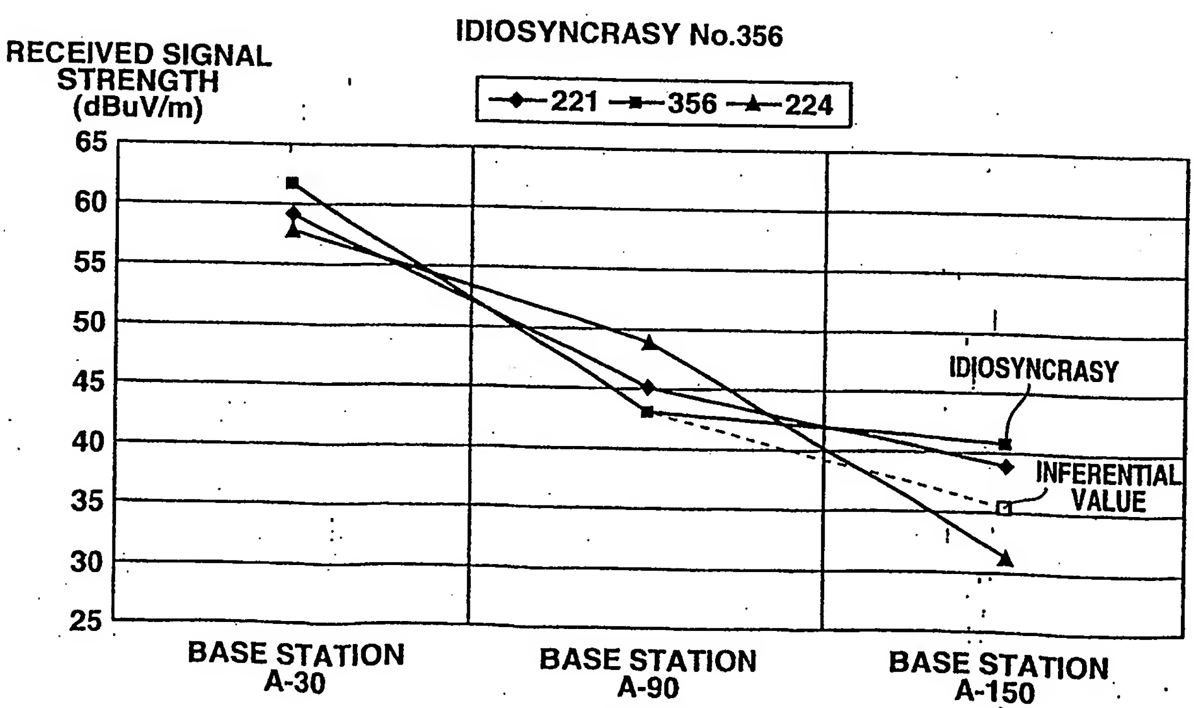


FIG.19A

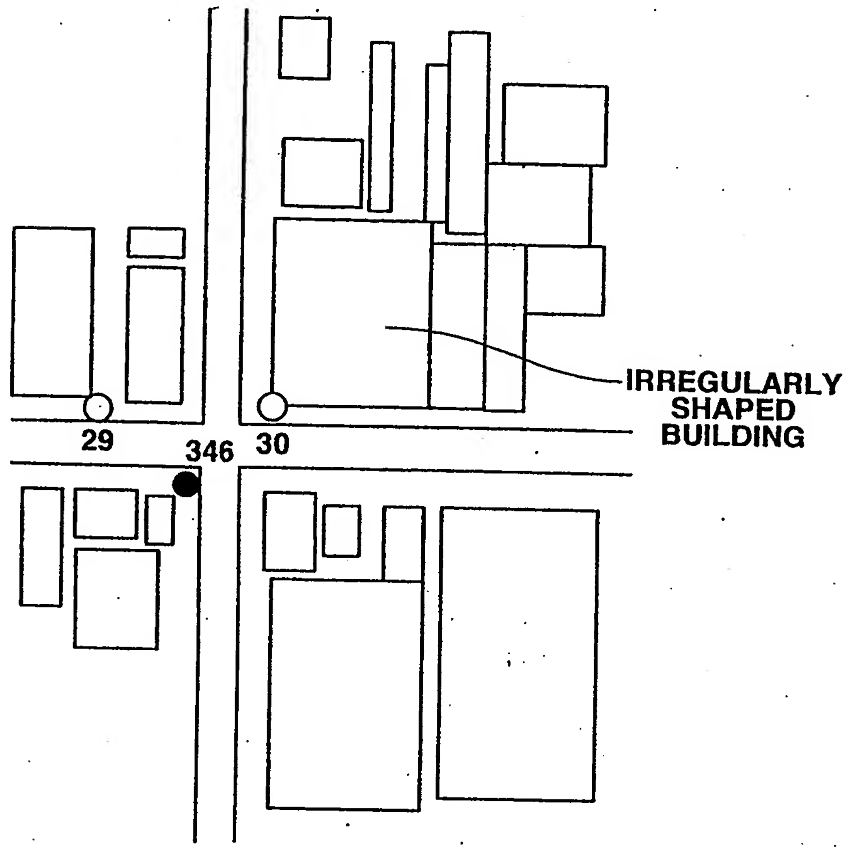


FIG.19B

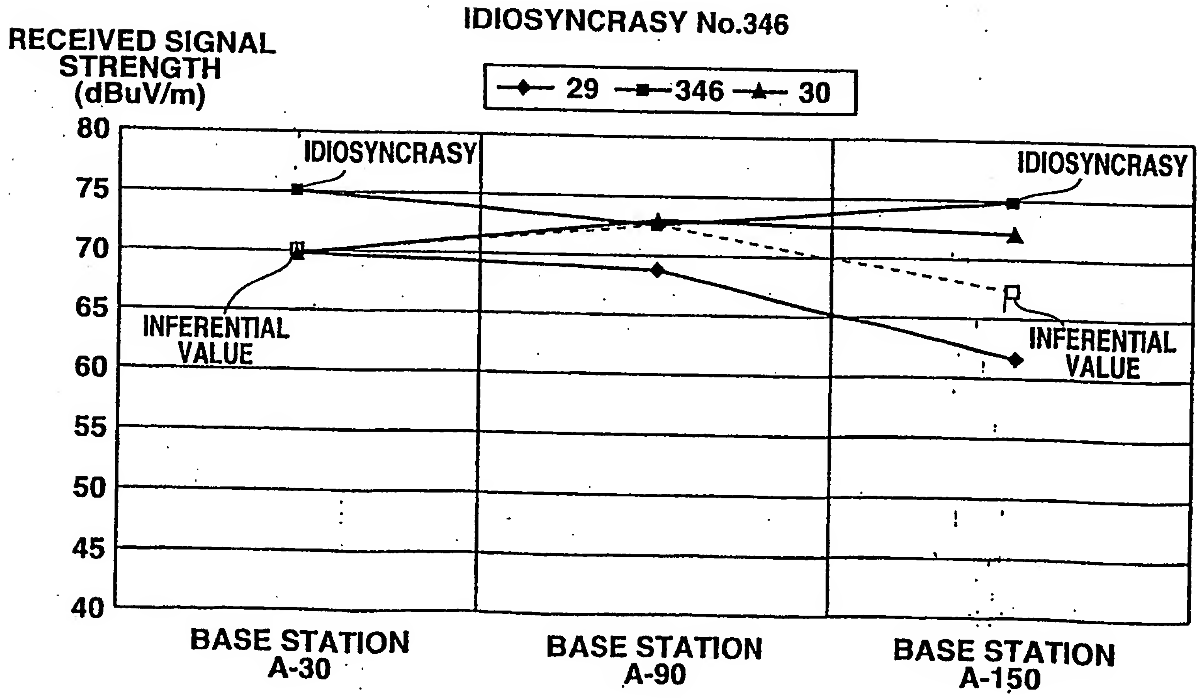


FIG.20A

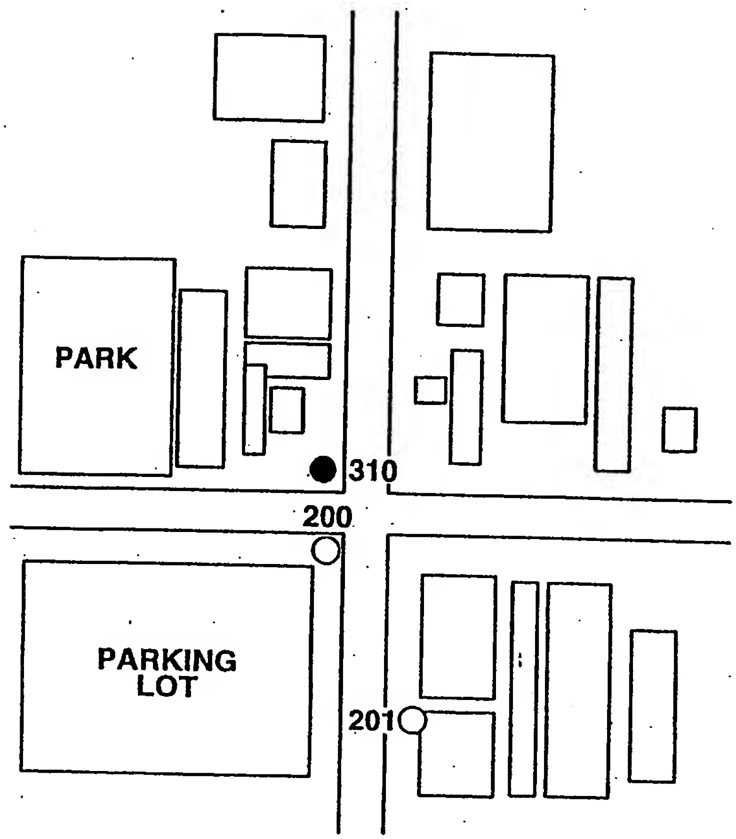


FIG.20B

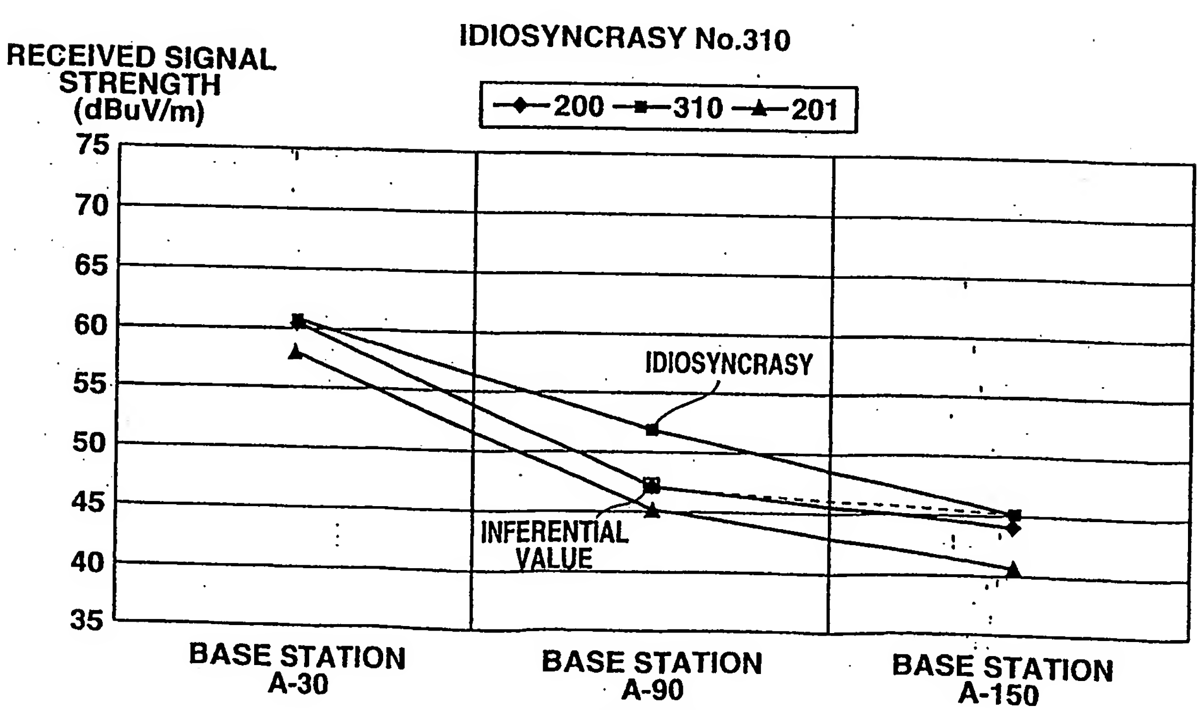


FIG.21A

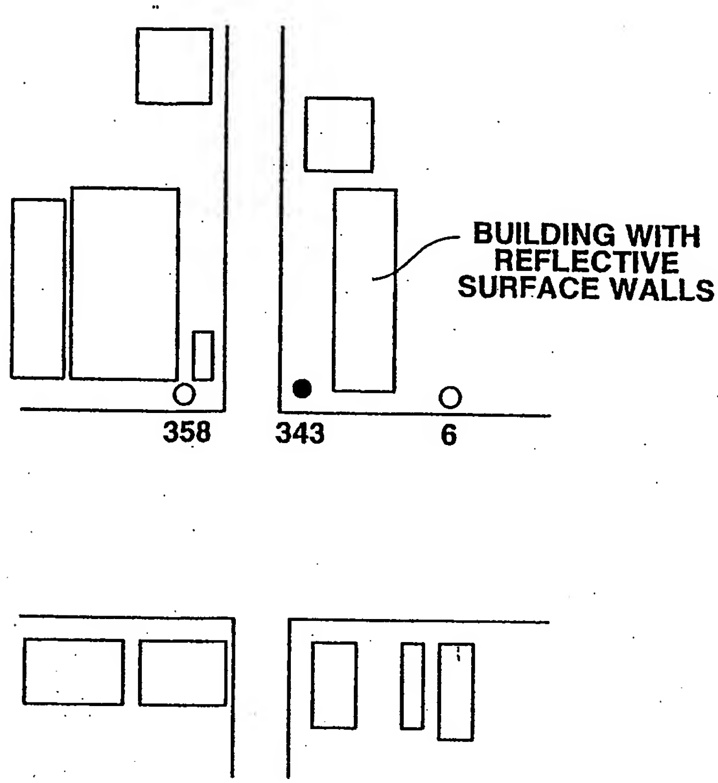


FIG.21B